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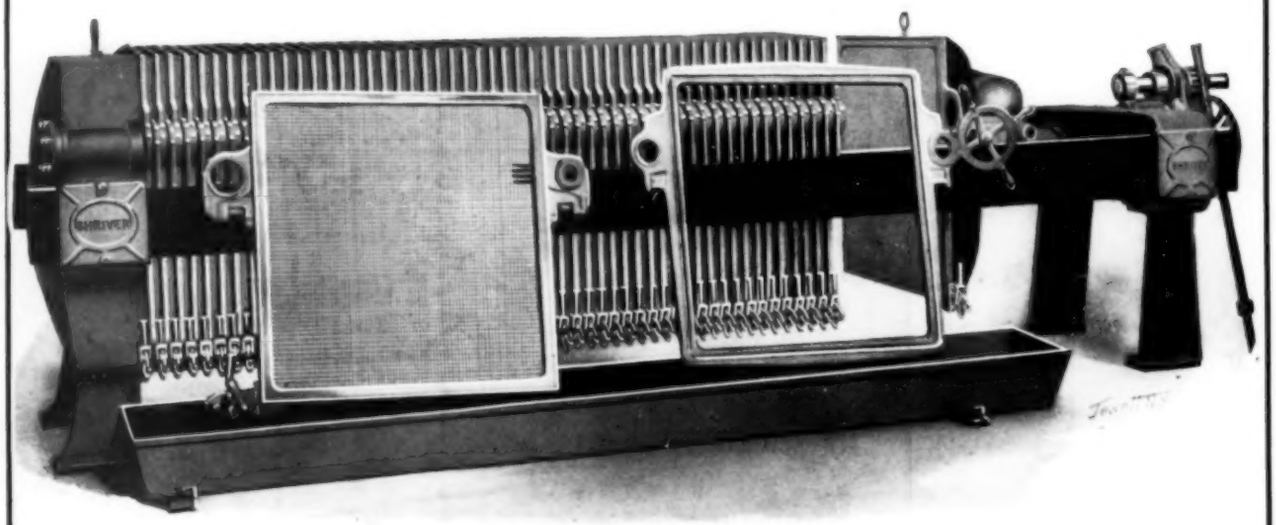

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Miss Liberty Is On the Wire

SUPPOSE you were sitting safe and comfortable at your desk—busy of course, but nevertheless very safe and comfortable compared with a night raider in No Man's Land—suppose you were sitting there and your 'phone should ring and your operator should tell you that "Miss Liberty is on the wire." You would be interested, wouldn't you? And then if a calm, firm voice should say "Hello, this is LIBERTY speaking; billions of dollars are needed, and needed NOW"—what would your answer be? Would you feel embarrassed? Would you halt or stammer? Would you be too surprised to answer? Or would you speak up promptly as though answering a call you were expecting?

Beginning September 28 and continuing for three weeks, Liberty is going to speak throughout the length and breadth of the land, and her message is going to be the same everywhere—"Billions of dollars are needed, and needed NOW!" Through the instrumentality of the colored supplement which accompanies this issue of CHEMICAL AND METALLURGICAL ENGINEERING we are trying to aid Uncle Sam in getting a connection with every loyal American. Literally and in fact, Liberty has a long-distance call in for YOU from France. Have you the answer ready?

Win-the-War Meetings for Fourth Liberty Loan

WE PUBLISH on advertising pages 310 and 311 the announcement of a plan for securing the organized coöperation of all employers of labor in the promotion of the Fourth Liberty Loan. We have given the subject valuable space because we deem it worthy of attention. In view of the fact that it has potential consequences far beyond the success of the loan, or even the winning of the war, we have no hesitancy in urging employers to act upon the suggestions there made.

It is well known that nothing is so effective in securing hearty coöperation in an organization as a feeling of personal responsibility among its members. Nothing is so potent for harmonious achievement of big results as a sense of personal pride among those who make the results possible. The tremendous impetus which Mr. Schwab has given to shipbuilding is due largely to a recognition of these facts; and he has accomplished the result by coming in personal contact with the workers and inspiring them with his own sense of the importance of their work in winning the war. Every employer, can, in like manner, be a leader of his own group of men and a center of influence that cannot be

overestimated. The means to this end is one or more win-the-war meetings of the employer with his employees; and the way in which the plan can be carried out systematically is described in the program booklet mentioned in the announcement. If the plan proves effective for the immediate purpose of promoting a Liberty Loan, why may it not be equally so for all industrial purposes after the war? The idea is worth a trial.

Rehabilitating Wounded and Crippled Soldiers

THE casualty lists are coming in fast and among the severely wounded there are many who will return with defective equipment in the way of legs and arms. The Government has very wisely planned to avoid, if possible, the pension errors of the days which succeeded the Civil War, and to provide in the place of them the greatest measure of rehabilitation of those that are crippled, so that they may take their places in the community. It is a bad thing to encourage idleness.

We must get over all prejudice against crippled men as a class and it behooves us to find places for those who have been physically injured but who are willing and able to work. Artificial legs and arms have been remarkably developed and we shall address ourselves for the present to a consideration of the industrial employment of one-legged and one-armed men. The blind belong in a different category.

Artificial legs made of hollow willow and leather are so articulated that a man with even two stumps can walk rapidly and for long distances. Physically, a great deal depends upon the stump. Most of these are easy to fit but occasionally there is one that always gives trouble. While a man with one or two wooden legs would seldom be an ideal porter or wheelbarrow operator, usually he can stand up and walk and do a man's work. Again, the one-armed man, properly fitted, is far better off then he used to be. Artificial arms are designed to meet special purposes and it is surprising the number of tools with which these may be equipped. They are not made to look like normal limbs. Some of them are wicked looking members, but are nevertheless remarkably efficient instruments. For ordinary occasions the cripple is provided with a "dress arm" which is an imitation of a normal arm and gloved hand.

Of course it all depends upon the man. There was an Irish lad who lost both legs, his left arm and all the fingers of his right hand in the great blizzard of '86 in New York. When he came out of the hospital they sent him to the poor-house. He told the authorities that if they would support him for a year while he was getting the education he needed he would take care of himself, but if they wouldn't he was resolved to live to be ninety and to make them take care of him all the time. They let him have his way and now he is president of a large bank in Minnesota. He drives his own automobile and even lights his cigar when he smokes. A man with such resolution is bound to succeed. We can't get that kind very often. Some men, as soon as they lose a member, proceed to become self-pitying nuisances, and of these not one in a hundred is worth his salt. But more often, it is said, men with artificial limbs develop an unusual quality of patience. They stick tighter than others to the problem in hand because they have had the training in patience as grown men to learn the art of using artificial limbs. Their employment is especially indicated in working at processes that need careful watching.

The American Red Cross has undertaken a rehabilitation institute for men injured in industrial and other accidents, taken from the hospitals. They are easily placed at present. But the time is near when such men will be coming out by the thousand. They must be employed if an unwholesome and bad situation is to be avoided. We therefore recommend to our readers that they look about their establishments and make note of the places where returned crippled soldiers may be employed. The records should be constantly studied and made available when tne time comes for us to take care of our heroes and to make life worth while to them.

Change in Meeting of Electrochemical Society

WE ARE advised as we go to press that the American Electrochemical Society has been obliged to change the place of its Fall meeting from Princeton University to Atlantic City, due to the fact that the War Department has taken charge of the University. The meeting will be held as scheduled, Sept. 30 to Oct. 2, with headquarters at the Hotel Traymore.

Wanted: Information on Blast-Furnace Smelting

IN THE present issue appears a paper on slag control in the iron blast-furnace in which is elaborated the practical applications of the author's slag-viscosity tables recently published by the Bureau of Mines. The thesis advanced is most important; it is that the chemical reactions in the smelting zone depend upon the "active range"—the interval between the temperatures of entrapment and escapement of iron globules in the slag—and that the fuel consumption of the blast-furnace varies directly with the temperature where the iron works itself free from the slag bath. Obviously a slag with a wide active range and yet labile at a relatively low temperature is the one desired in these days of actual and prospective coke famine. The slag-viscosity tables enable the metallurgist to select scientifically the optimum composition fitting his slag-forming ingredients.

This rather novel conception of furnace action has much to commend itself to the theorist speculating upon the reactions proceeding in the smelting zone of the blast-furnace. It throws welcome light upon the reactions of carburization and silicification and may explain the peculiar characteristics of electric pig iron. But ready acceptance may be somewhat delayed on at least one consideration which merits close attention.

Feild's conception of slag action rests upon the assumption that the molten iron is imprisoned in the just-forming slag when viscosity of the latter reaches a value of approximately 10. For the time one may readily accept the oft-repeated statement that the reduction of iron oxide attains completion quite high in the furnace shaft at a low temperature (possibly 800 deg. C.). The present hypothesis implies that carbonization and sulphidation of the spongy mass should also proceed

at about the same temperature. At 1135 deg. C. the austenite-cementite eutectic melts, and with the settlement of the charge it is superheated and readily dissolves any excess metallic constituent. Therefore at 1400 deg. C., the approximate temperature at which the slag reaches a viscosity of 10, the iron has doubtless all fused into fiery drops, and it is very difficult to see how this liquid metal can become trapped in the slowly moving slag; one hardly expects water bubbles to be absorbed in warm tar. Oozing slag certainly will engulf solid fragments, but can it absorb drops of thin liquid?

However one may feel about the "trapped iron" hypothesis, a consideration of the subject opens up most interesting questions on carbonization and sulphidation reactions, on the mechanism of slag formation, on the physical characteristics of many oxides at high temperatures, on the temperature-concentration equilibrium of many important reactions, and on the relation of viscosity to reversible reactions at interfaces. The solution of these cannot fail to be most fruitful in tangible results to scientists as well as works-metallurgists. It is to be hoped that the Bureau of Mines may not only continue the attack upon such fundamental lines, but endeavor to initiate and coördinate individual effort on the part of investigators in many university and research laboratories.

Ship Losses and Ship Construction

ACCOUNTS of the performance of shipyards are likely to create an unduly favorable impression as to the extent to which the destruction of vessels by submarines is being met. Many of the reports published are more or less fragmentary, frequently referring to the performance of a single week. Launching of hulls has lately exceeded by a large margin the actual completion and delivery of vessels. The production of ship plates has greatly exceeded the quantity that has actually gone into hull construction. Ship construction by the United States or the United Kingdom has sometimes been compared with the vessel losses of the same countries, whereby there is left out of the reckoning the important item of losses by neutrals being far in excess of their vessel construction. Finally, vessel losses are reported in gross register tons while vessel construction is reported in deadweight tons, while roundly speaking it requires about 125 tons deadweight to be built to make up for 100 gross tons lost. The public mind has been confused by the inadequacy of the presentations and the net result of the confusion is to create an impression that combatting the submarine by new construction has proceeded farther towards success than is really the case.

The total of allied and neutral vessel losses through enemy action and marine risks since the war began are as follows, in gross tons, including 182,829 tons of Allied shipping interned in enemy ports at the opening of the war:

Year		Gross Tons
1914	.....	681,363
1915	.....	1,724,720
1916	.....	2,797,866
1917	.....	6,623,623
1918	(Seven months)	2,396,590
	Total.....	14,224,162

Thus the losses have amounted to almost 30 per cent of the world's merchant marine and obviously it is no small task to replace the tonnage. Now, what was the impression created in the average mind by the announcement made in Washington September 4 by the Shipping Board, that shipbuilding in the United States in August broke all records for any country for a month? A very favorable impression, no doubt. The record, however, was of 340,145 tons deadweight of vessels completed, that breaking the American record of 263,571 tons in May, and the British record of 295,911 tons in June. It compares, moreover, with a January output of 88,507 tons by the United States and 37,852 tons by the United Kingdom. The proper conception is that if American shipbuilding in August broke the records, that is so much the worse for the records.

The record of 340,145 tons deadweight completed by shipyards in the United States in August represents no more than about 280,000 gross tons, for comparison with the gross tonnage of vessels lost. At this record rate it would require 50 months for the shipyards of the United States to make up for the vessel losses from the beginning of the war to August 1, 1918. If our August tonnage broke the British record, the indication would be that the British contribution would not be sufficient to cut the time in half.

The Shipping Board began operations in August, 1917. From the beginning to August 1, 1918, the deliveries on its account have been 245,700 tons deadweight of contract vessels and 1,326,156 tons of requisitioned vessels, making a total of 1,571,856 tons deadweight, equivalent to less than 10 per cent of the total losses of 14,000,000 gross tons.

The purpose of these comparisons is merely to show that the job of replacing vessel losses is still to be done. The facts that Great Britain broke her record as lately as last June, and with only 295,911 tons, and that the United States broke her record as lately as August, with only 340,145 tons, show that the job has only been fairly undertaken.

A great deal of information as to what is required in order to build ships has been obtained. For instance, when we severed relations with Germany in February, 1917, we thought steel plates were unobtainable and directed our attention to wooden hulls because we had a great many trees. The wooden-ship chimera died a hard death. The condition for weeks past has been that plate mills are delivering, for account of shipbuilding in the United States, a quantity equal to 650,000 tons deadweight of vessels per month, yet 340,145 tons deadweight of vessels completed in August, barely more than one-half as much, broke the record, and some of the vessels were not steel at that. The launchings in July had been 631,944 tons. Plates, of which 18 months ago we thought we had none available, are in plentiful supply. The bottle-neck is equipment, engines, boilers and a thousand and one other things, as the Director of Shipbuilding plainly and frankly stated recently. The job lies before us and the speeding-up still needed is chiefly on the part of shops all over the country that must furnish engines, boilers, cranes and all sorts of equipment of a dozen other descriptions with which to furnish the hulls.

Readers' Views and Comments

Science and the German Language

To the Editor of Chemical & Metallurgical Engineering

SIR:—Anent your most interesting editorial on the use of the German language at present, might it not be well to allow the study of German, stamping on every German page the following:

> This language has some admirable characteristics but it has certain notable defects such as lack of any true word for gentleman, sportsman or sincerity.

In this connection, we might say that the German word for sportsman is simply a Germanized form and is pronounced *Schporhtman;* the word for gentleman is *Herr* which means lord or master; the word for sincerity is *Aufrichtigkeit* which means uprightness. These are poor, lame substitutes for our words and both in denotation and connotation have quite different meanings.

CHEMIST.

Organic Reagents for Research Purposes

To the Editor of Chemical & Metallurgical Engineering

SIR:—I am interested in the letter of Dr. Mees of the Eastman Kodak Co., relative to their manufacture of organic chemicals. In this connection your readers will doubtless be glad to know that the Research Laboratory of Chicago is principally engaged in the manufacture of such products. We are now making in small quantities a series of organic reagents and will begin work in the near future on a series of acridine dyestuffs which have proved successful in chemotheropy.

G. HEYL.

Chicago, Ill.

Evaluation of Zinc Dust

To the Editor of Chemical & Metallurgical Engineering

SIR:—In looking over my copy of CHEMICAL & METALLURGICAL ENGINEERING of July 1, I note the reprint of my paper on the Evaluation of Zinc Dust, read at the last meeting of the American Society for Testing Materials. I wish to direct your attention to two errors which appeared in this paper as follows:

1—The correction tube as shown on page 33 of your magazine for July should not be closed at the bottom. The accompanying sketch will show this in its correct form.

2—At the bottom of the first column on page 33 the sentence beginning, "The temperature change, on the other hand, . . . according to Boyle's law," should read, "The temperature change, on the other hand, . . . according to Charles' law."

I suggest that you make these corrections in an early issue of your magazine in order that your readers may have no misunderstanding regarding the article.

LOUIS A. WILSON.

Palmerton. Pa.

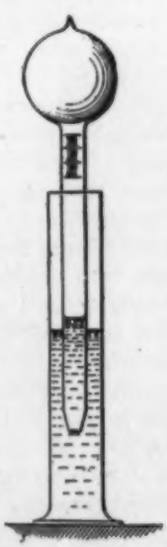

FIG. 2. CORRECTION TUBE

Recovery of Molybdic Acid for Steel Mills

To the Editor of Chemical & Metallurgical Engineering

SIR:—I have just read the article on "Recovery of Molybdic Acid for Steel Mills" in your issue for Aug. 15, 1918. This article in all its essentials is a word-for-word copy of an article of mine published in the *Journal of Industrial and Engineering Chemistry*, vol. 7, page 213.

W. D. BROWN.

Carnegie Steel Co., Duquesne, Pa.

To the Editor of Chemical & Metallurgical Engineering

SIR:—I am very much surprised to learn that Mr. W. D. Brown of the Carnegie Steel Company had previously published the note on the "Recovery of Molybdic Acid for Steel Mills." The information which I contributed to your journal some time ago was given me by another chemist and I had no knowledge that it had ever been published or that it was a copy of another article. If this was taken from Mr. Brown's publication I wish to express an apology for seeming to publish the material as my own.

W. H. LYNAS.

Columbus, Ohio.

Research Preparedness in the Zinc Industry

To the Editor of Chemical & Metallurgical Engineering

SIR:—The interesting letter of Mr. J. H. Hastings, commenting upon and accenting my paper in your issue of July 1, presents some views as to detail construction of retorts and charging that may be good but are not those I had in mind.

The briquetting of zinc charges appeared to have been about as well worked out by me two years ago as was desirable, but since then I have run across a process that may displace all pressing so far as roasted charges are concerned, and cut the cost of the act from one dollar per ton to perhaps 25 cents. This process will not do, however, for the lime-process briquet which I feel will be the briquet of the future, for several reasons.

Mr. Hastings makes the statement that because of using the vertical retort the maintenance charges will increase, but gives no reasons. My conclusions would be that maintenance would be less, because there would be no sagging of retort, and less slag action on vertical sides than on a horizontal bottom.

The savings that can be made in zinc distillation are indeed large, but so radical in action as to defer the attention of distillers until the electrothermic furnace using the lime process in the hands of mine owners and waterpower companies in the Northwest, makes it necessary for them to economize or go out of business.

Comments like those of Mr. Hastings show that some of us are thinking, which outside of quick dollar-making is almost a lost art.

PARKER C. CHOATE.

A tin-smelting plant has lately been erected at Leeuwpoort (Transvaal), and it is understood that operations will begin shortly.

Western Chemical and Metallurgical Field

Cyanide.

CANADIAN mills using cyanide are furnished their solvent by the Cassel Cyanide Company, Ltd., of Glasgow, Scotland, at a price which varies from month to month and which is based on the rates which the maker pays for the raw materials. The ruling price for the chemical to the Canadian mills during the early part of 1918 was in the neighborhood of $0.25 per pound (plus duty) for standard cyanide titrating 100 per cent KCN, delivered to the nearest railroad station. The sodium cyanide normally supplied titrates to the equivalent of 130 per cent KCN or more, but the price to consumers is calculated on the basis of 100 per cent KCN, as noted above. In the early part of 1917 a shortage was threatened on account of a prospective labor shortage, the tendency of the military authorities in Great Britain then being to overlook all peaceful industry and sacrifice everything for the vigorous prosecution of the war. On the proper representation being made in London by the combined Canadian, South African and Australian governments, all these difficulties were removed, and now, so long as ships are available to cross the Atlantic, no further trouble need be anticipated.

In the western United States there is plenty of cyanide available on the market in the form of one-ounce eggs. Comparatively little is taken by mills, gold and silver cyanidation being on the wane, for well-known reasons. Much more is used in gas-fumigation of citrus trees. The United States supply is furnished almost exclusively by Roessler & Hasslacher Chemical Co., from their Perth Amboy plant. In the Mexican markets cyanide from both the American and Glasgow firms is being offered at reasonable prices.

Town Planning in Copper Camps.

Some managers can readily see the advantage of retaining contented workmen after asking their account-

FIG. 1.—THE PLAZA

ant to tell them the cost of the labor turnover. Then they are almost ready to become paternalists in an effort to keep a man after they have got him. Others are more obtuse, even to requiring I. W. W. propaganda to drive home the fact that only a "floater" will inhabit an old-fashioned construction camp.

An enlightened view, in fact the only tenable view, of housing conditions has been taken by the management of the New Cornelia Company when developing their oxide mine and leaching plant at Ajo, Arizona. Situated in the midst of an absolute desert at the southern edge of the state, the natural surroundings are as unenticing and the heat of summer as enervating as can possibly be imagined. Yet their operations, calling for the highest skill in both mining and metallurgical departments, demanded at all times a stable group of expert workmen.

An idea of how well the effort to counteract the natural unattractiveness of the surroundings has succeeded may be had by the accompanying view of part of the plaza.

FIG. 2.—HOUSES FOR WORKMEN

Water is pumped from wells many miles distant, and is therefore at a premium, yet enough can be spared for the needs of this beauty spot which forms the community center, surrounded on all sides by colonnaded walks and modern store-buildings. Neat little houses, properly designed for hot weather use, furnish the men and their families comfortable homes, but no praise is too great for the real effort displayed to relieve the terrible desert monotony with a spot which delights the eye.

The officials of the Phelps-Dodge Corporation had more to work upon at Tyrons, New Mexico, than did their competitors at Ajo, yet one has as much admiration of the way they have improved their opportunities. Their settlement is approached by a wonderful roadway over the continental divide, and is situated in attractive rolling hills, covered with scrubby trees and bushes where foliage is almost evergreen. How well their engineers have availed themselves of these advantages is seen from the picture of the Mexican houses built on Bellotal Avenue, which is merely one of the roads winding back through the little valleys converging to the plaza itself. One familiar with the squalor of the ordinary pueblo almost wonders if the Mexican appreciates such advantages as would the Western American.

War-Profits in Metal Industries.

The Federal Trade Commission has submitted a lengthy report at the request of the Senate, giving their available information on the present range of profits in various industries. In the case of the metal industries, this information is largely gained by cost-finding by the experts in the Commission's employ.

In general, the commission declares that profiteering exists, much of it due to advantage being taken of the necessities of heavy production, but some of it to "inordinate greed and barefaced fraud." Some instances of fictitious padding of cost accounts were found, by such means as large depreciation charges, increased salaries of officials, adding interest to cost, charging new construction to repairs, placing inflated value on raw materials, and manipulation of inventories. The outstanding revelation is the heavy profit made by the low-cost concern working under a price fixed by the government to stimulate production from even the higher-cost institutions. This not only produces an economic situation fraught with hardship to the consuming public, but strengthens the dominating position of the low-cost plants.

In the case of steel, the United States Steel Corporation is cited as an instance of the fully integrated mill; its profits in terms of the total amount invested show net earnings as follows:

	Per Cent
1912	4.7
1913	5.7
1914	2.8
1915	5.2
1916	15.6
1917	24.9

Mills which start with steel furnaces are generally very prosperous. In some cases individual mills have made objection that the government prices are too low for them to show returns on investment of from 40 to 319 per cent on the business of 1917.

Figures show that 21 copper companies, including a large proportion of the so-called "high-cost" companies, made 1917 profits of from 1 to 107 per cent, an average of 24.4 per cent, as compared to 11.7 in 1913. Probably over 70 per cent of the production is marketed at profits of over 20 per cent on the investment. There does not appear to have been any concerted action in putting up prices; the high level is attributed to the scramble among the Allied governments for the metal. In this trade, as in others, however, there is a strong tendency to increase and maintain prices against the forces of competition. For instance, custom smelters continue to hold in force deductions for the risk of carrying copper, which risk no longer exists. On the other hand, some large mining companies have long-term contracts still in force which enable them to have their ores smelted at less than present cost.

No unusual profits exist in the zinc industry, taken as a whole, except in the case of the New Jersey Zinc Company, whose position is due to the possession of an ore body of unusual richness and purity. This company published its profits for 1916 as being 72.5 per cent, and they paid dividends amounting to 76 per cent, while the Trade Commission's figures indicate a real profit of 95.9 per cent for that year.

The International Nickel Company has a natural monopoly on nickel in the United States, owing to its ownership of mines in Canada. It has maintained prices at the pre-war level, and its increased profits have been due to increased output demanded by the war. While "profiteering" in this case is not charged, the Commission questions whether the company might not have been satisfied with smaller prices and smaller profits in an essentially war material.

Program of Fourth National Exposition of Chemical Industries

Grand Central Palace, New York

Week of Sept. 23, 1918

The addresses comprise a series of symposiums devoted to a consideration of

THE DEVELOPMENT OF CHEMICAL INDUSTRIES IN THE UNITED STATES, NOTABLY SINCE JULY, 1914.

Monday, September 23rd.

Afternoon (2:30 P.M.) Opening Addresses.

CHARLES H. HERTY, Chairman, Advisory Committee.

WM. H. NICHOLS, President, American Chemical Society.

F. J. TONE, President, American Electrochemical Society.

G. W. THOMPSON, President, American Institute of Chemical Engineers.

Evening (8 P.M.) Motion Pictures.

WATER POWER, ITS DEVELOPMENT AND USE

*The Falls of Iguizu, Argentine; Great Latent Powers.

*Power of Wealth—Hydraulic Development.

*Power Transmission (4 reels).

Canadian Shawinigan Falls Power Development and Its Surrounding Chemical Industries (3 reels). (Shawinigan Water & Power Co.)

*Fixation of Atmospheric Nitrogen at Niagara Falls and Feeding the Soil With It (2 reels). (American Cyanamid Co.)

Tuesday, September 24th.

Afternoon (2:30 P.M.) Symposium: ACIDS and CHEMICAL ENGINEERING.

E. J. PRANKE (American Cyanamid Co.), Development of Nitric Acid Manufacture.

EMERSON P. POSTE (Elyria Enameled Products Co.), Developments in the Manufacture of Glass Enameled Apparatus.

Evening (8 P.M.) Motion Pictures.

THE OIL INDUSTRIES

*The Story of a Cake of Soap.

*Light from the Rocks; Natural Gas (4 reels).

Lake Asphalt Industry (Barber Asphalt Co.).

Asphalt Roofing Industry (Barber Asphalt Co.).

Asphalt Colloids (Barber Asphalt Co.).

(9 P.M.) Speakers:

J. A. SWITZER (University of Tenn.), Waterpower Potentialities of East Tennessee.

HERBERT C. HENEGAR (American Zinc Co.), Mineral Resources of East Ten-

nessee. (Representing Knoxville Chamber of Commerce.)

Wednesday, September 25th.

Afternoon (2:30 P.M.) Symposium: POTASH.

C. A. HIGGINS (Hercules Powder Co.), Recovery of Potash from Kelp.

LINN BRADLEY (Research Corporation), Recovery of Potash from Iron Blast Furnaces and Cement Kilns by Electrical Precipitation.

JOHN W. HORNSEY, Potash from Desert Lakes and Alunite.

ALFRED DE ROPP, JR. (American Trona Co.), Potash from Searles Lake.

Evening (8 P.M.) Motion Pictures.

Electrical Precipitation of Potash from Cement Dust (Research Corporation).

*Colloid Chemistry.

The Operation of a By-Products Coke Plant (2 reels). (H. Koppers Co.)

Moving a Forest to France (4 reels). (Southern Pine Association.)

The Story of Potash—Production at Searles Lake.

Thursday, September 26th.

Afternoon (2:30 P.M.) Meeting: AMERICAN CERAMIC SOCIETY—Chairman, L. E. Barringer.

L. E. BARRINGER—Manufacture of Electrical Porcelain (Illustrated, Motion Picture).

A. V. BLEININGER—Recent Developments in the Ceramic Industries.

H. RIES—American Clays.

F. A. WHITAKER—Manufacture of Stoneware (Illustrated, Slides).

J. B. SHAW—Fuel Conservation.

S. C. LINBARGER—Carborundum Refractories.

These will be followed by motion pictures as designated for the evening program.

Evening (8 P.M.) Motion Pictures.

THE CERAMIC INDUSTRIES

Glass Making (Corning Glass Co.)

†The Making of Cut Glass.

Manufacture of Electrical Porcelain (General Electric Co.).

†The Making of Pottery.

(9 P.M.) Speakers:

J. A. SWITZER (University of Tennessee), Waterpower Potentialities of East Tennessee.

HERBERT C. HENEGAR (American Zinc Co.), Mineral Resources of East Tennessee. (Representing Knoxville Chamber of Commerce.)

Friday, September 27th.

Afternoon (2:30 P.M.) Symposium: METAL INDUSTRIES.

LEONARD WALDO (Rumford Metal Co.), Development of the Magnesium Industry.

ALCAN HIRSCH (Hirsch Laboratories), Ferro-Cerium Pyrophoric Alloys.

THEODORE SWANN (Southern Manganese Corp.), Ferro-Manganese.

JOS. W. RICHARDS (Lehigh University), Ferro Alloys of Silicon, Tungsten, Uranium, Vanadium, Molybdenum and Titanium.

Evening (8 P.M.) Motion Pictures.

CARELESSNESS: THE DESTRUCTION OF LIFE, WEALTH AND RESOURCES

Careless America (Firestone-Universal).

*The Crime of Carelessness.

*The Workman's Lesson.

Keep Your Business Going (3 reels). (General Fire Extinguisher Co.)

*Vaccines for Prevention of Disease (4 reels).

Saturday, September 28th.

Afternoon (2:30 P.M.) Symposium: INDUSTRIAL ORGANIC CHEMISTRY.

S. P. SADTLER (S. P. Sadtler & Son), Industrial Organic Chemistry and Its Progress.

C. A. HIGGINS (Hercules Powder Co.), Kelp as a Source of Organic Solvents.

GEO. H. TOMLINSON (Kinzinger, Bruce & Co., Inc.), Wood as a Source of Ethyl Alcohol.

Evening (7 P.M.) Motion Pictures.

Manufacture of Zinc Oxide (New Jersey Zinc Co.).

Manufacture of Genuine Wrought Iron Pipe (3 reels). (A. M. Byers Co.)

*From Log to Lumber (4 reels). (Southern Pine Association)

The Wonderland of the Appalachians (3 reels). (Clinchfield Railway)

From Coal Mine to Corn Field—Production and Use of Ammonium Sulphate (The Barrett Co.).

(9 P.M.) Speakers:

J. A. SWITZER (University of Tennessee), Waterpower Potentialities of East Tennessee.

HERBERT C. HENEGAR (American Zinc Co.) Mineral Resources of East Tennessee. (Representing Knoxville Chamber of Commerce.)

Synthetic Phenol

Our attention has been directed to an error which occurred in the make-up of the article of Mr. A. G. Peterkin in our issue for September 1, 1918. The titles of Charts I and II were inadvertently reversed and should be changed in order to make the descriptions clear. Chart I represents the new process of Dennis and Bull, and Chart II the old Barrett process. If the titles are transposed the references in the text will be correct and no further confusion will follow.

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*Films so indicated are shown by courtesy of Bureau of Commercial Economics.

†Films so indicated are shown by courtesy of Ford Motor Co. Films are all single reel unless otherwise indicated.

Colorado Meeting of the American Institute of Mining Engineers

An Account of the Technical Sessions Held at Denver and Colorado Springs—Members of the Institute Visit Mines and Metallurgical Plants at Denver, Colorado Springs, Cripple Creek, Pueblo and Leadville

THE one hundred seventeenth meeting of the American Institute of Mining Engineers, held in Colorado during the week of September 2, was the first to be held in the Centennial State for twenty-two years. The meeting was a pronounced success, worthy of Colorado engineers and comparing favorably with the Institute's Western meetings in recent years. All this was in spite of the bad weather which pursued the convention almost throughout the week, culminating on Thursday in a heavy snowstorm which almost stalled the party in its Pike's Peak automobile trip, and prevented the visit to the Golden Cycle mill.

MONDAY, SEPTEMBER 2

The meeting opened on Monday, September 2, with a technical session on Metallurgy, held in the Brown Palace Hotel in Denver. There was a large attendance of engineers, but unfortunately very little discussion of the papers developed. In the absence of the authors, all of the contributions except that by C. A. HANSEN were read by title. The paper on Electrostatic Precipitation by O. H. ESCHHOLZ brought forth a large amounts of written discussion, while so many members present asked for rather extended time in which to present their views that the chairman of the meeting, Mr. T. B. STEARNS, announcd that a special session on precipitation would be held later in the week. Discussion of this paper was therefore deferred until Thursday evening at Colorado Springs, and is reported farther on.

Immediately after adjournment, the members and guests were taken to the ferro-alloy plants near Utah Junction, the equipment of which was described in a paper at the morning session by ROBERT M. KEENEY, manager of the Iron Mountain Alloy Co.

Visit to Ferro-Alloy Plants

The plant of the Iron Mountain Alloy Co. contains one 1200-kw., three-phase furnace, and one 1800-kw., three-phase furnace, giving a total capacity of 12 long tons of ferromanganese per 24 hours. The former furnace is supplied with power by three 400-kw., single-phase transformers, having a ratio of 13,200 to 75 volts, and connected Δ/Δ. The voltage on the furnace is 72 volts. The 1800-kw. furnace is likewise connected to three 600-kw., single-phase transformers. The furnace shells in both cases are 18 ft. long, 8 ft. wide, 7 ft. deep, and are lined with magnesite. The electrodes on the smaller furnace are of carbon, 17 in. in diameter, and on the large furnace 24 in. in diameter. No roofs are used, and regulation of electrodes is by hand.

The plant of the Ferro Alloy Co., also at Utah Junction, contains one 750-kw., three-phase furnace, to which power is supplied by three 250-kw. transformers, connected Δ/γ to give 129 volts on the furnace cables, the transformer ratio being 13,200 to 75 volts. The furnace operates with an actual voltage of 120 volts, and produces about 3 tons of ferrochrome per 24 hr. from 40 per cent Cr_2O_3 ore. The furnace consists of a steel shell of circular cross-section, 8 ft. in diameter by 7 ft. deep, lined with magnesite, and having three 12-in. carbon electrodes. A 450-kw. furnace, of the same size as the 750-kw. furnace, is also operated on chrome ore. This furnace is three-phase in appearance, but operates electrically as a single-phase furnace. There are three vertical carbon electrodes 8 in. in diameter with a conducting carbon bottom. Power is supplied by three 150-kw., single-phase transformers, two of which have a ratio of 13,200 to 95 volts, and one a ratio of 13,200 to 100 volts. From each transformer, one lead goes to one vertical electrode, and one lead to the carbon bottom,

so that the transformers are electrically independent. The furnace voltage varies from 90 to 95 volts.

At intervals, 150-kw., single-phase furnaces are operated on ferrotungsten. These furnaces have one vertical graphite electrode 4 in. in diameter, with a water-cooled steel bottom-contact. The furnace shells are 4 ft. in diameter, and are mounted on trunnions, the slag being poured by tilting the furnace. All of the electrodes are regulated by hand. The chrome furnaces are operated without roofs and the tungsten furnaces with roofs.

Tour of Mountain Parks

After the excursion to the electric-furnace plants, and luncheon at the Denver Club, came the incomparable automobile ride over Gennessee Mountain through Denver's mountain parks. Many stopped en route at the pottery of the Herold Porcelain Works in Golden. This most pleasant day closed with an informal dinner at the country club.

Oxygen and Sulphur in the Melting of Copper Cathodes

At the morning session on metallurgical subjects, STANISLAUS SKOWRONSKI, research engineer of the Rariton Copper Works, presented two papers on the furnace refining of copper cathodes.

Discussing his first paper, the author gave the results of analyses of samples of copper taken from a refining furnace at 30-minute intervals when poling under both a coke and charcoal cover. The results are presented in graphical farm and show that in the oxidation period the reversible reaction

$$Cu_2S + 2Cu_2O \rightleftarrows 6Cu + SO_2$$

starts toward the right immediately and is completed when the oxygen content of the charge is about 0.35 per cent. It apparently reverses when poling has brought the oxygen down to about 0.08 per cent. The sulphur in cast copper is mostly absorbed from the carbonaceous cover; therefore charcoal gives a lower-sulphur copper than does coke.

It is becoming better understood that the "surface set" on the pitch of copper is directly controlled by the sulphur and perhaps certain reducing gases, such as carbon monoxide and hydrogen, rather than by the oxygen; that sulphur raises the "set" or overpoles the copper, thus necessitating a certain amount of oxygen which therefore depresses the "set" to counterbalance the action of the sulphur.

In these two charges sampled, the "pitch" of the copper was the same, yet owing to the lower sulphur in the product melted under charcoal, its oxygen content is also much lower, affording great improvement in the quality of the copper. The refiner did not know how much sulphur was present in his final product; he simply worked the copper to the desired pitch, and the sulphur present in each charge determined the amount of oxygen necessary to give the proper "surface set" on the copper.

Relation of Sulphur to Overpoling of Copper

In Mr. SKOWRONSKI'S second paper, the common definition of overpoling was advanced; that is "copper which has been exessively reduced during the poling period of the refining process" and so porous as to be unfit for use. When melting very pure cathode copper in a graphite crucible under charcoal and in contact with green wood, the resulting ingots (free of sulphur and very low in oxygen) had a "level" set and proper "pitch." Overpoling is therefore thought not due to a lack of oxygen—it is apparently impossible to overpole copper by over-reduction if it does not contain sulphur and possibly other reducing gases. High-sulphur alloys were made by melting cathode chips with the addition of weighed amounts of cuprous sulphide. When melted in uncovered crucible, the oxygen tended to increase with the sulphur, thus giving in most cases no evidences of overpoling. When melted under charcoal, however, the oxygen was reduced approximately 75 per cent and the high-sulphur ingots were badly overpoled. Another study of the electrical characteristics of copper ingots showed that a low conductivity was due to oxygen rather than sulphur.

From these results, it is evident that cuprous oxide counteracts the effect of sulphur, either by increasing the solubility of sulphur in copper, or, as pointed out by Johnson, by inducing a physical condition of equilibrium between the sulphur, tending to "overpole" the copper, and the cuprous oxide, tending to "underpole" it. Yet neither theory explains the fact that when a charge of copper is "overpoled" it cannot be righted by a simple addition of cuprous oxide, but the charge must be reworked to set copper.

"It takes a comparatively large amount of cuprous oxide to counteract a trace of sulphur; this explains why, in the refining of copper, the gases from fresh fuel will often "overpole" the copper during the casting period, and also why copper cannot be held in the furnace at the proper pitch more than a few hours. It also explains the limit of recharging cathode sheets into the furnace after the copper has been worked to the proper pitch, the sulphate present on the cathode sheets overbalancing the equilibrium established between the cuprous oxide and the sulphur."

The author concludes that both oxygen and sulphur affect the pitch of the copper, leaving open the questionable effect of hydrogen and carbon monoxide.

Discussing this paper Mr. PHILIP L. GILL pointed out the difficulty of maintaining a balance between cuprous oxide and the reducing gases when casting conditions are favorable to segregation, and he thought that many experimental results could be ascribed to the fact that copper cast in small chills set differently than in large wire-bars. He was always able to overpole copper in refining furnaces, even when melting sulphur-free cathodes with low-sulphur coal and when poling under charcoal. In such cases of overpoling a 100,000-lb. bath, the copper absorbed at least 20 pounds of something in 20 minutes, this something he thought more likely to be carbon monoxide and hydrogen from the green wood than the SO_2 from the furnace gases.

Electrolytic Zinc

An important paper by C. A. HANSEN on this subject has already been abstracted in METALLURGICAL AND CHEMICAL ENGINEERING, May 1, 1918, Vol. 18, p. 481. Mr. J. L. VARDLEY thought that a more timely publica-

tion of such important information would have prevented the duplication of much tedious research. Also that since at the present time there are three very large plants operating on three widely different ores by processes independently and simultaneously perfected, the electrolytic production of zinc was evidently not such an abstruse problem as published information would lead one to believe.

Replying to a query, Mr. Hansen stated that he was absolutely sure that the Tainton or any other process operating at a high current density and acidity must have a substantially pure electrolyte in order to deposit zinc successfully.

Antimony Smelting in China

CHUNG YU WANG presented notes supplementary to his book on Antimony, showing drawings and photographs of various types of furnaces in use in the different Chinese smelters, and detailed information on furnace charges and operation. The author notes that under the stimulus of the war price of $900 (Mexican) per ton of regulus, a number of small smelters were erected so that the total capacity of 23,000 tons per year is now in existence. He presents two detailed cost sheets showing that the pre-war cost of $63 per ton of regulus (1911) had jumped to $180 in 1915.

"Due to the lack of capital, and of mutual coördination and coöperation among the smelters and the short-sighted policy of the directors of the different companies, there has not been any marked progress in the metallurgy of antimony in China. Obviously an important line of future progress should be in the direction of eliminating the heavy losses due to volatilization of the metal during the successive steps of treatment. If the loss could be lowered from the present 20 per cent to 10 per cent, or possibly less, an annual saving of at least $600,000 would be effected, which would more than pay back the capital outlay for such alterations and additions to the existing plants."

Mr. Wang also advocates the substitution of a mechanical roaster for the long reverberatories now in use to oxidize the crude or rich ore, the improvement of the liquation furnaces, the adoption of gas-firing, and the installation of Cottrell plants. Discussing the use of "*couverture*," the author notes the well-known fact that the "market always demands good stars with fern-like structure on the slab of regulus before its acceptance. The appearance of such structure does not actually indicate the relative purity of the regulus, but is only the result of cooling it under the cover of a properly prepared starring mixture—in the absence of a proper English term, I shall call it by its French equivalent *couverture*—whose fusion point is lower than that of antimony, which is 630 deg. C. Of course, when the regulus contains impurities like sulphur, arsenic, lead or iron to any appreciable quantity, its surface shows it by specks, by a leaden appearance or by an ill-defined appearance of the fern-like structure. On the other hand, I have seen many a slab of regulus, with impurities above what are considered to be the limits imposed by buyers, whose stars are still bright and well-defined with all the appearance of well refined regulus. Now since the buyer demands such unnecessary adornment on the regulus, he has to pay for it; for the costs for starring 1 ton of regulus amount to from $10 to $60 (Mexican), according to the market price of the antimony compound used. The proper procedure for charging any of the above mixtures is as follows: The mixed couverture compounds (usually antimony tioxate plus soda or potash), are immediately charged into the reduction furnace as soon as the skimming is finished. The doors are closed and vigorous firing is maintained; as soon as it is observed that the mixture is completely melted, ladling commences. Each ladle dips into the molten metal and, in coming out, picks up a certain quantity of the molten couverture, which, when poured out rapidly together with the metal into a hot mold, completely covers the metal on all sides." The thickness of the solidified couverture varies from 1 to 2 mm. on all sides, 5 to 7 mm. on top, and varies from $\frac{1}{3}$ to $\frac{1}{4}$ the weight of the regulus produced. About $\frac{1}{3}$ of the compound is lost by volatilization and by wall-fluxing; it is hammered from the slab and re-used until it becomes foul, when it is resmelted.

Metallography of Tungsten

This subject was discussed at length in a scholarly paper by ZAY JEFFRIES. After briefly reviewing the manufacture of wrought tungsten products, the author discusses at considerable length the relation between thoria contents, temperature and grain-growth as explained by the germinative temperature laws. This subject is of importance in the manufacture and life of lamp filaments. For instance, an ingot made of very fine metallic powder welded at the minimum temperature is too fine grained, brittle and hard to be worked. By heating this ingot just above the germinative temperature the ingots are much more readily deformed. On the other hand it is desirable to keep the grain size as small as possible since the resistance to grain growth inherent in the small size gives better results in the lamp filament, for the operating temperatures in an incandescent lamp are in the grain-growth range.

"Tungsten is not an easy metal to polish. It is so resistant to the action of abrasion of the polishing powders that levigated alumina can be substituted for tripoli to advantage just preceding the rouge.

"White cast iron has been used to advantage as a mounting material for small pieces of tungsten which cannot conveniently be handled without some sort of a mounting. The piece of tungsten to be mounted is put in a mold and the molten cast iron poured around it. The white cast iron and tungsten are so nearly the same hardness that flat surfaces can be produced on the tungsten during polishing. It is sometimes very difficult to mount and polish the smallest tungsten wires. This has been accomplished in a successful manner, however, on wires less than 0.001 in. in diameter. One satisfactory method is as follows: An ordinary malleable iron $\frac{3}{8}$-in. (9.5-mm.) pipe cap is planed on the closed end outside. It is then drilled on the inside to a plane parallel to the outside plane. A round cover glass is put on the inside of the pipe cap, on which are placed several pieces of the small tungsten wire to be polished. Another cover glass is placed on top of these wires, after which the opening of the pipe cap is filled with powdered glass. It is then put in a furnace, being maintained in an upright

position, and heated for about 5 min. to a temperature of 800 or 900 deg. C. It has been found in many experiments that this temperature does not affect the structure of tungsten wire. The pipe cap with contents is then removed from the furnace and the glass which has congealed is pressed tightly into the pipe cap and allowed to cool slowly. The metal portion on the end of the pipe cap is then turned off in a lathe and the glass is exposed. This glass containing the samples of tungsten is polished in the ordinary manner until the tungsten wires are exposed, and the polishing is completed in the ordinary manner.

"Boiling hydrogen peroxide is used for etching most of the tungsten products. Tungsten may also be etched electrolytically with good results, using a solution of sodium hydrate for electrolyte."

Tungsten is particularly distinguished because it is brittle at room temperature when composed of small equiaxed grains, yet when of fibrous structure it is ductile and pliable. Commonly metals act exactly oppositely. Mr. Jeffries explains this phenomenon by a careful consideration of the variation in plasticity and cohesiveness of the crystalline particles and the amorphous cement binding them together. At room temperatures the somewhat malleable grains cannot deform to any considerable extent before failure occurs through the amorphous cement. In fibrous tungsten, on the other hand, the grain distortion has so arranged the boundaries that rupture is forced to take the shorter path through the more ductile grains, even though a larger absolute amount of amorphous material is then present.

Prof. C. H. FULTON, of Case School of Applied Science, presented a noteworthy paper on "The Condensation of Zinc from Its Vapor," which we will publish in full in a later issue.

Manufacture of Ferro-Alloys in the Electric Furnace

ROBERT M. KEENEY presented a lengthy account of the manufacture of the ferro-alloys of chromium, manganese, molybdenum, tungsten, and vanadium, giving in tabular form furnace sheets of a great many charges. This part of the contribution is so packed with information that justice cannot be rendered in an abstract, and those interested in these alloys will refer to the original.

The latter half of the paper gives the results of many experiments on ferro-uranium, the records of his failures being no less valuable than of his successes.

"Ferro-uranium was developed not because of any particular need for uranium in steel manufacture, but because of the large quantity of sodium uranate, $Na_2U_2O_7$, that was accumulating as a by-product of radium production. At the start, uranium exhibited one of its fundamental characteristics, its strong affinity for carbon and its tendency to form carbides. Also, in this early work it was found that no fluxing material except fluorspar could be used with sodium uranate; if either lime or silica was added, the uranium remained in the slag with practically no reduction, thus exhibiting its second characteristic, its strong affinity for oxygen."

In the attempt to make a 20 per cent uranium alloy, steel turnings were melted, and then a mixture of sodium uranate, coke and fluorspar added. It was found that until there is 0.4 lb. of carbon in the charge for every pound of uranium very little reduction occurs. From 0.4 to 0.7 lb. carbon the percentage of uranium in the alloy varies little and the percentage of carbon in the alloy remains between 3.5 and 4.0 per cent. Both analytical and microscopic examinations indicated that when there was enough carbon present to form the double carbide, $Fe_2C.U_2C_3$, the ferro-uranium held the uranium, and only then. Since the carbon in the alloy was considered excessive, decarbonization with iron scale alone and with silica was unsuccessfully attempted, for the reason that the tendency to form iron uranate results in slogging all the uranium. Melting with U_3O_8 was equally a failure. Neither can ferro-uranium be made using silicon as a reducer with a commercial recovery or a low-silicon alloy.

Since satisfactory low uranium alloys were not forthcoming, attempts to produce the pure metal were made. Unsuccessful attempts resulted with sodium, carbon, aluminium and silicon in a gas furnace, but in a stationary Siemens electric furnace with magnesite walls and carbon bottom "uranium metal was reduced by carbon to a button containing over 90 per cent uranium and from 3.5 to 4 per cent carbon. The production of this low-carbon metal, with the minimum amount of carbon charged, depends entirely on manipulation of the electric furnace, a very high temperature being necessary. The product is an alloy of uranium carbide and uranium metal. The silicon and iron can be kept at about 1.5 per cent each, and the vanadium at 1.25 per cent, with the oxide used. The uranium recovery in a single operation will be from 50 to 60 per cent. The material left in the furnace is a mixture of pure oxide and carbon, which can be charged again as soon as its carbon content is determined. In this way, the ultimate recovery of uranium is high, well over 85 per cent. The power consumption is high, because pure uranium oxide is being reduced. It averages about 8 kw.-hr. per pound of metal." Two per cent carbon or more is necessary in the final product in order that all the uranium oxide be reduced, while if the button of hot sponge-metal is removed from the furnace it immediately oxidizes.

"To secure the proper temperature, the furnace must arc all the time. Regular charging is necessary. The uranium metal is allowed to form a sponge on the bottom of the furnace, which gradually builds up. Directly beneath the electrode, this sponge is pasty, but not fluid. The charge forms its own furnace lining. When a run is finished, the button of uranium metal is removed from the furnace. The unreduced residue is re-treated with another charge," giving practically complete recovery. The button contains 4.4 per cent carbon, 1.4 per cent silicon, 1.4 per cent iron, 1.3 per cent vanadium.

Given a low-carbon metal the next problem was to add it to molten steel in such a manner that its uniform incorporation would ensue. Experimenting with molten steel in an electric furnace, it was found that uranium metal was not a good addition agent because it must be in the steel bath for a considerable time to melt, while it oxidizes and slags nearly as rapidly as it becomes molten. With the experience already gained it was

now found possible to make a 50 per cent ferro-uranium with less than 5 per cent carbon by mixing steel turnings with the necessary U_3O_8 and coke, together with a considerable quantity of fluorspar. The entire mixture was added slowly to the furnace at the rate of 2 pounds every 5 minutes. The resulting alloy then gave a recovery of 50 to 70 per cent when used as an addition to steel designed to contain 4 to 2 per cent uranium, respectively. Additions for low uranium steels may be made in the ladle; if considerable quantity of the alloy is to be added, however, it must be made in a skimmed furnace within one minute of pouring.

"Ferro-uranium is brittle, has a high density, and when it contains over 20 per cent uranium has a tendency to be phyrophoric, this tendency increasing with the percentage of uranium. A 3 to 5 per cent carbon alloy, with less than 15 per cent uranium, has a dense non-crystalline structure, and is dull gray in color. When the uranium content reaches 18 to 20 per cent, small bright crystals appear; and as the alloy approaches 50 per cent uranium, these crystals become larger, longer, and more distinct. From 18 per cent up, the alloy has a brilliant, flaky fracture. At 18 per cent it is hard to break, but at 50 per cent uranium it breaks easily. With the commercial 50 per cent alloy no graphitic carbon is present if the total carbon is under 5 per cent, but if there is over 5 per cent carbon, this excess carbon is usually graphitic. Any of these alloys has an entirely different appearance if cooled from a white heat in water, this treatment giving it a granular and dirty appearance. If the carbon is less than 1.5 per cent, the alloy has a dense gray appearance and is difficult to break. Under the microscope, the uranium appears to be present as the double carbide of iron and uranium, $Fe_3C.U_2C_3$, in a eutectic mixture of iron and carbon.

"Uranium metal with over 90 per cent uranium has a dull black color. It is dense in structure, but powders easily. It is very phyrophoric, and draws a long spark when struck across steel or another piece of uranium metal. Uranium carbide is also phyrophoric, but is more flaky in structure than a mixture of uranium metal and uranium carbide."

TUESDAY, SEPTEMBER 3

The second day's social affairs planned for the Mining Engineers were sadly marred by wet, misty weather, which rendered impossible the many cañon trips contemplated. Most of the members attending arrived in Colorado Springs on the morning trains, and were served luncheon at the recently completed Broadmoor Hotel, where were established the permanent registration headquarters. Impressive services were held early in the afternoon in memory of the late Dr. James Douglas, brief addresses by Messrs. JENNINGS, MATHEWSON, INGALLS and O'BRIEN recounting his many sterling qualities.

Preceding the technical session were shown moving pictures of the Canadian reconstruction hospitals for wounded soldiers. The inspiring work they are there doing will point the way for us to provide adequate and honorable occupations for our own returned boys. Dr. RICHETTS then exhibited films showing the interesting operations of the Ajo works of the New Cornelia Company, speaking extemporaneously in explanation of the pictures. A joint technical session on Coal and Coke was held with the Rocky Mountain Coal Mining Institute with A. E. CARLTON in the chair, while G. H. CLEVENGER presided over a simultaneous meeting on Ore Dressing and Cyanidation. The evening was enlivened by a reception and dance to visiting members and their guests.

Technical Session

Hand-Sorting of Mill Feed.—A typical sorting plant on Coeur d'Alene ores handles 800 tons of ore between 1½ and 4 in., from which 50 tons of shipping ore of about 45 per cent lead and 150 tons of waste is removed at a cost of $125. Mr. R. S. HANDY, the author, believes that straight crushing and milling is not only cheaper, but is metallurgically more economical and efficient than hand-sorting followed by milling of the residue. The ore could be prepared for milling by crushing at 3 cents per ton, as compared to 16 cents in the sorting plant. The recovery on this rich fraction would be much higher than the average, since the ore does not slime and the jigs get all the coarse galena. Assuming that all the slimes passing the jigs is from this ore and would be lost it would amount to but 50 lb. of lead per day.

If there is no advantage in sorting out shipping product, there must be less advantage in sorting out waste, when the cost is 50 or 60 cents per ton of waste rejected. There is an economical advantage in milling as against hand-sorting that seems to be little considered, which is in the grading of the products. The author presents curves which show a definite economic peak where the various factors of recovery, grade and cost combine to give a maximum net money return to the operator, and concludes that "the crux of the whole matter is, 'What can you do with the hand-sorted product in the mill?' and not, 'What does the mill do on the feed it is getting?' The only sure test is to run the mill on a hand-sorted product long enough to determine what grade of concentrate and of tailings can be achieved. I am sure a test of this kind would surprise many of the advocates of hand-sorting by demonstrating the enormous economic advantage to be gained by the opposite method of treatment. If any process in the mill produces a higher-grade concentrate than it is practicable to sort out by hand, or if any process in the mill produces a tailing equal in grade to that sorted out by hand, then it is advisable to mill the hand-sorted material."

In the discussion of this paper, Mr. A. STANLEY HILL takes issue with the author, stating that at the Hecla Company's property the ore-sorting plant does 23 per cent of the work at 15 cents per ton of material sent through, whereas it costs 36 cents to mill a ton of ore. To handle the sorted ore a heavy expenditure in mill construction would be necessary. "In the crushing plant no material is obtainable for any purpose other than milling, whereas in the sorting plant we obtain waste suitable for mine filling (an acute problem, as tailings could not be shipped from the mill except at prohibitive rates)." In order to be convincing, Mr. Handy's statement that recrushing and rejigging produces less sliming than occurs in the bed of the jig when bringing

up the grade of the concentrate should be supported by sizing tests and proper analyses.

Mr. W. L. ZEIGLER pointed out that the advantages of hand-sorting depend mainly upon the physical characteristic of the ore in question, especially of the possibility of removing extremely hard gangue, of the chance of hand-separating ore containing minerals with difficulty separated by concentration or which slimes excessively.

CLARENCE A. WRIGHT called attention to the Joplin practice, where the hoisted rock is dumped on a 4- or 5-in. grizzly. Many barren flint boulders are sorted here, the quantity reaching 20 per cent at times, the inclusion of which these operators feel would lower the capacity of the mill and increase operating costs.

Replying to the critics, the author said he thought Mr. Hill had not considered that the large proportion of his milling cost is in the handling of middlings and fine material, which products would hardly be increased by handling the coarse high-grade ore. If Mr. Hill's mill feed consisted of nothing but the material which is sorted, his lead recovery and costs would put the milling world to shame.

Fine Grinding Plant of the Barnes-King Co.—In a description of this plant, Mr. J. H. MCCORMICK notes that the all-slime treatment was adopted in order to treat ores from several mines differing somewhat in nature. One hundred and fifty tons of ore per day are crushed in coarse breakers, and then ground in slow-speed Chilian mills. "These mills make a remarkable reduction, but leave some fine sand to be slimed in the tube-mills. Repairs are required rather frequently and access to make repairs is difficult, making the mills unpopular with the attendants. Crushing costs, however, compare favorably with other modes of coarse crushing, being, in fact, rather less than those shown by larger plants using ball-mills. An undesirable feature of these mills in a slime plant is that their product is too uniformly fine for regrinding in a pebble-mill without undue consumption of pebbles."

The balance of the paper presents a description of the flow-sheet, together with data as to the metallurgical recoveries and costs. As an instance, Table I is selected:

TABLE I—PRINCIPAL ITEMS IN COST OF MILLING 52,885 (Dry) TONS

	Total Amount Used	Total Cost	Per Ton — Amount	Per Ton — Cost
Lane steel	21,576 lb.	$2,596.79	0.41 lb.	$0.0491
Grinding pebbles	534,000 lb.	5,796.85	10.10 lb.	.1096
Cyanide	40,490 lb.	13,138.04	0.77 lb.	.2484
Lime	585,823 lb.	3,352.99	11.08 lb.	.0634
Zinc shavings	44,835 lb.	9,010.90	0.85 lb.	.1704
Steam coal	489,000 lb.	2,167.35	9.25 lb.	.0410
Borax glass	4,530 lb.	887.09	0.08 lb.	.0168
Lumber-tailings dam	29,892 ft.	777.52	.56 ft.	.0147
Commercial hydrochloric acid	7,574 lb.	990.16	0.14 lb.	.0187
Commercial sulphuric acid	17,819 lb.	488.46	0.34 lb.	.0092
Fuel oil	1,210 gal.	176.98	0.02 gal.	.0033
Diaphragms No. 4	222	579.80	.....	.0110
Crucibles No. 275	23	1,351.46	.....	.0255
Mint and express charges	.....	3,491.26	.....	.0660
Elevator bucket belt, 13-in., 7-ply	.....	.....	.....	.0017
Elevator buckets 12-in., 10-gal.	.....	.....	.....	.0013

Effect of Oxygen on Precipitation of Metals from Cyanide Solutions.—Mr. THOMAS B. CROWE'S paper on this subject excited much favorable comment. He became convinced that nascent hydrogen, given off by dissolving zinc, is the real precipitant of gold from cyanide solution; thus while dissolution of the metal is an oxidizing process requiring oxygen for its operation, precipitation is essentially opposite, a reducing process requiring hydrogen. In precipitating solutions containing dissolved air much of the zinc was wasted because its evolved hydrogen had first to combine with and remove oxygen before getting an opportunity to precipitate zinc.

"Laboratory tests on the application of a vacuum to solution before the addition of zinc-dust confirmed my theory. Large tests were tried, apparatus was designed that would continuously apply a vacuum to solution during its flow to the precipitation presses, and gradually the vacuum system of precipitation worked its way into our mills, with the result that the zinc consumption has been cut in half, which fact is especially gratifying to us during the war period with its prevailing high prices.

"A thorough scrutiny of our former work revealed the fact that, for dissolution purposes on our particular ore, the cyanide solution strength was much higher than was necessary, having been kept high for the sake of good precipitation. In fact, the solution strengths in our mill had been reversed—the strongest solution was the barren; and this being used as a wash on the filters, occasioned high cyanide consumption. The high strength of the barren solution was caused by the necessity of adding lump cyanide at the head of the precipitation process to insure low-grade solutions to be used in washing.

"With the installation of our vacuum system, we found that perfect precipitation could be maintained without the addition of lump cyanide, and today our mills are running with the highest solution strength in the agitators, and not in the barren tank. This, together with a generally lower solution strength in all parts of the mill, has allowed a material reduction of cyanide consumption."

J. V. N. DORR, in commending the paper, said that in his opinion Mr. Crowe had made the greatest single improvement in the chemical end of cyaniding in the last 20 years, while Mr. G. M. TAYLOR, manager of the Victor and Independence Mills said that in these two plants the saving in zinc and cyanide, in treating 2000 tons of ore daily, amounted to $30,000 per year. Chairman CLEVENGER said that without endeavoring to detract from Mr. Crowe's work in the least he thought the same thing had been done inadvertently in vacuum filtering in Butters' type machines for many years.

G. T. HANSEN said that in his practice he found that heating the pregnant solutions to 170 deg. F. to precipitate copper partially accomplishes deoxidation of the solutions, although at a higher cost.

Roasting Cripple Creek Ores for Amalgamation and Cyaniding.—A. L. BLOMFIELD and J. M. TROTT described the methods used at the Golden Cycle custom mill. They bed as class A ores containing less than 2 per cent CaO, and higher lime ores, which require 50 per cent longer time in the roaster ore separately bedded as class B. The crushed ore is fed to an Edwards duplex roaster; operating details, temperatures, and mechanical features, together with the chemical reactions normally proceeding, are explained at length.

The production of soluble sulphides and sulphates must be avoided because of its action as a cyanide, and in deoxidizing the solutions. "Calcium sulphate, formed either in the roasters or by reaction of soluble sulphates in the ore on meeting the lime in solution, is decidedly

deleterious. The hot ore warms the crushing solution. This becomes saturated with calcium sulphate and precipitates as the solution cools. These crystals fill pipes, launders and Dorr thickeners, render filter mats and clarifying mats impermeable, coat Merrill filters, frames and cloths and form a deposit on the zinc and zinc boxes. In class A ores these troubles are comparatively unimportant, although considerable time is required to neutralize the solutions, whereas class B ores often require none."

While an "over-roast" will produce excellent results in a standard cyanide plant, a better residue can be obtained by a cheaper and less complete roast if the amount of soluble sulphide, total sulphur, HCl-soluble and Na_2CO_3-soluble sulphur is held under close control by chemical analysis.

"The limits of insoluble sulphur are: Class A, 0.10 per cent; class B, 0.15 per cent. The limits of soluble sulphide are: Class A, 0.10 per cent; class B, 0.15 per cent.

"Experience has shown that class B ores give good residues with higher total and insoluble sulphur and soluble sulphide, than class A. The chemical reasons for this are still obscure, but it is possible that the interaction between the sulphates and sulphides in the roasters, as noted above, gives a larger amount of each as a secondary reaction, and these then do not have so deleterious an effect in the treatment."

In order to adopt this delicate treatment certain details of the treatment subsequent to roasting were essential. Thus, blankets catch the coarse coated gold much better than do plates. The colloids must be eliminated so that the ore may be leached exceedingly fast. Otherwise a "slip-up" in one roaster will cause a rich residue by complete deoxidation of the solution. Removal of colloids is effected in a Dorr bowl classifier. A further precaution to be observed is that "change of solution must be made quickly to allow a good margin between an over-roast and an under-roast. On the sands, this is done by the back flow or wash solution in the classifiers."

Leaching tanks must be quickly filled with a semi-dewatered product in order that the sands may not rest too long in a dead solution in the early stages. Slimes must be aërated soon after classification, and more time must be given for agitation.

Excavating Tailings at Ajo.—Following as it did the film of the New Cornelia's operations, Mr. FRANKLIN MOELLER'S paper describing the Hewlett tailing excavator in operation at Ajo was enhanced in value. This excavator empties one of their 5000-ton leaching tanks each night. It is entirely similar in principal to the iron ore unloaders so familiar along the lower Great Lakes, with, of course, many minor modifications to fit the conditions at this plant. As Mr. E. P. MATHEWSON pointed out, the mechanical and electrical control stops which prevent the bucket from digging closer than six inches from the side walls and bottom of the tanks has resulted in an uninjured lead-lined tank which is the prime desideratum in any leaching operation.

Grinding Resistance of Various Ores.—A very important paper by LUTHER W. LENNOX, presented preliminary results of an investigation still under way. "In an attempt to investigate the relative grinding resistances of a number of ores now being milled in this country and Alaska, the management of the Portland mills requested samples of average mill-run of ore from various companies. The request met with a ready response, indicating the desire of all operators to gain information on the subject." A quantity of each ore was coarse crushed and separated in various sizes, from which fractions a "standard feed" was prepared according to the following table:

PREPARED STANDARD FEED

Mesh	Cum. Per Cent Retained
10	12.95
14	27.98
20	39.47
28	49.88
35	57.11
48	63.01
65	68.71
100	74.01
150	79.69
200	82.41

One pound of this prepared ore, one pound of water, and 74 ¾-in. steel balls were then placed in a small tube-mill, 8 x 12½ in., rotated at 84 r.p.m. for a definite time, dried and screen-analysed.

"The method adopted for computing the results is that of Rittinger based on the law that work done in crushing is proportional to the surface exposed by the operation, or to the reciprocal of the diameter. For plotting the screen tests, the mesh (reciprocal of diameter) and the cumulative per cent of oversize are used as coördinates. The area between the feed and product curves will be proportional to the 'apparent work' done. The apparent work is in turn inversely proportional to the resistance of the ore to grinding; hence, the area between the curves is inversely proportional to grinding resistance.

"Unfortunately, we are unable to deal accurately with the material below 200 mesh, which is where most of the work done is represented. Microscopic measurements seem to offer the only accurate method. Curves plotted in the area below 200 mesh seem to follow no definite law, as that of a hyperbola. Many operators may feel but little interest in what happens after a certain fineness (say 48 mesh) is reached, but this does not render it necessary to measure the total work done on the whole of the ore."

The following table gives the comparative grinding resistance of various ores as determined by this method:

Comparative Grinding Resistance	Source of the Ore
1.33	Calumet & Hecla jig tails.
1.16	British Columbia, Tonopah, Belmont.
1.00	Portland mill-feed (Development Co.)
0.94	Smuggler Union.
0.92	New Cornelia Copper Co.
0.83	Liberty Bell.
0.81	Butte and Superior.
0.80	Humboldt mine (Smuggler Union).
0.80	Tonopah, Belmont.
0.79	Goldfield Con., cyanide feed.
0.71	Goldfield Con., flotation feed.
0.71	Alaska Treadwell, quartz & schist.
0.70	Miami Copper Co.
0.69	Alaska Gold Mines Co.
0.63	Homestake, unaltered ore.
0.63	Arizona Copper Co.
0.61	Nevada Con., pit ore.
0.53	Morenci, Phelps-Dodge.
0.53	Calumet & Arizona, roaster ore.
0.52	Alaska Treadwill, schist.
0.46	Copper Queen, mill feed.
0.38	Utah Copper.
0.37	Ray Consolidated.

R. B. KILIANI in favorably commenting on the paper said that it would prove a god-send to those who had to "guess" at the proper grinding equipment to install

in a new mill. Given the method, the comparative grinding resistance could now readily be determined with very simple apparatus, following which definite information as to just what each type of ball-mill could be expected to do could be immediately had by referring to the performances of that grinder already operating in another mill having ore of approximately the same relative resistance.

WEDNESDAY, SEPTEMBER 4

The party left Colorado Springs by special train for the Cripple Creek district where the day was spent at the mines and mills. In the early days of Cripple Creek the ore was mostly shipped to smelters but very soon mills were located at Colorado City and Florence. With the decreasing value of the ore, however, came the necessity of building local mills by the Independence, Portland and Vindicator companies. This has rendered possible the treatment of dumps, waste and low-grade ore reserves.

The cyanide process as now applied to the higher-grade Cripple Creek ores is briefly as follows: Coarse-crushing in rolls; roasting in Edwards, Pearce turret or Holthoff furnaces; passing the pulp over blankets for recovery of free gold; fine-grinding in tube or Chilian mills. The pulp is then treated either by straight agitation and filtration, or, after desliming, the sand is leached and the slime agitated, thickened to a suitable density, and filtered.

Radium

The technical session held in the evening at Colorado Springs was opened by an interesting lecture on radium by Dr. RICHARD B. MOORE of the Bureau of Mines. He exhibited some of the radium products recovered by the joint efforts of the National Radium Institute and the Bureau of Mines. In the discussion Mr. W. A. SCHLESSINGER pointed out the fact that many carnotites contain soluble sulphates which precipitate dissolved radium; also that the available carnotite comes from many different localities, necessitating different treatment according to the nature of the ore. Low-grade carnotites can be concentrated, but the concentrate is so very fine and so hard to filter that it is almost impossible to extract the radium contained. Luminous paint has been largely developed within the last year, and is a mixture of the purest zinc sulphide and radium in suspension in a quick-drying varnish. About 500 milligrams per month is being consumed for this purpose alone.

Molybdenite in Colorado

Mr. D. H. HALEY described the operations at Climax, Colorado, where low-grade deposits are being developed. Treating 0.9 per cent MoS_2 ore yields a recovery of 10 lb. of MoS_2 per ton. While the ore-dressing is still in a state of development, most of the losses are due to the presence of oxides. Promising laboratory methods for sulphidizing these have been discovered which reduce the tailings to 0.15 per cent MoS_2 but the necessary reagents are not now available in quantity. At present they are increasing the capacity of the mill to 1000 tons per day, which will have an output far in excess of the whole previous world's supply.

THURSDAY, SEPTEMBER 5

Electrostatic Precipitation.—On Thursday evening there was a most interesting discussion of this subject, deferred from Monday's program in Denver. Mr. DORSEY LYON was in the chair.

In the original paper of Mr. ESCHHOLZ he pointed out that the possibilities of electrostatic precipitation were known a century ago, but that its practical application awaited the perfection of the alternating-current transformer. Operating conditions require very rugged equipment because it must bear the brunt of occasional surges caused by treater breakdown, and the periodic oscillations produced at each half cycle on breaking the rectifier arc.

The problem of converting high-tension alternating current to high-tension unidirectional current has received considerable attention. Although many devices, such as mercury rectifiers, hot-cathode converters, or kenotrons, high-voltage direct-current generators, unsymmetrical electrodes, etc., have been advocated, the mechanical rectifier is still in use on practically all commercial treater circuits.

The mechanical rectifier makes a positive separation between the alternating current supplied to it and the unidirectional impulses sent to the treater, occurring when electrode separation draws the arc to the breaking point. The rectifier cannot, of course, suppress a sustained short-curcuit caused by complete breakdown in the treater chambers, or by contact of electrodes. Under such conditions, it operates to limit the current until the circuit breakers open.

A delicate oscillograph shows that the voltage sustained across the treater is almost constant, its effective value reaching 97 per cent of the peak. This sustaining of the treater voltage is caused by the comparatively slow rate of treater discharge. In fact, under the usual condition of moderate clearance of gas at a velocity of 6 ft. per second, obtained in a tube 12 in. diameter, 15 ft. long, the average velocity of the dust particles, at right angles to the gas stream is, roughly but 0.8 in. per second, while complete precipitation of the same number of particles during the interval between breaking and making rectifier contact would require a velocity of 900 in. per second.

Systems depending upon the use of a mechanical rectifier for the conversion of high-tension alternating current to direct current may be classified with respect to the source of power.

A. Low-tension alternating-current generator for treater load only:

(1) Single-phase generator supplying power to single transformer-rectifier-treater unit.
(2) Single-phase generator supplying power to two or more transformer-rectifier-treater sets operated in parallel on the low-tension side.
(3) Multi-phase generator supplying energy to one or more transformer-rectifier-treater sets from each phase.

B. Low-tension alternating-current industrial or lighting mains having a relatively large capacity as compared with treater demand, and supplying one or more transformer-rectifier-treater sets.

C. High-tension alternating-current main supplying energy directly to potential regulator-rectifier-treater sets.

The author strongly prefers system A-1. Other systems than those mentioned have been urged from time to time on the score of low cost, but the author points out that the advantage of low first cost is illusory since the electrical equipment costs only from 10 to 15 per cent of the cost of the treater and is only 2 to 7 per cent of the value of the yearly recovery.

In discussing the electrical features of the process Mr. FISCHER of the Research Corporation said that system A-1 is widely and correctly used in large sectionalized plants, but that system B is simplest and will become more popular. It must be installed in large-capacity circuits. Resistances are valuable because they absorb the surges. System C has never been seriously applied.

Mr. VIETS of the Research Corporation said that the transformer in system A may reflect surges like a mirror back to its closely connected generator. System B produces fewer oscillations building up dangerous electromotive forces. The treaters at Tooele were changed from system A-1 to B because the latter gives precipitation due to the increased power input which is possible, and a smoother wave form is produced. No undesirable surges are produced in the main smelter circuits. On the other hand Mr. MURPHY of Anaconda said that in the huge new plant being built, system A-1 will be used. Extensive tests were made on A-1, A-2 and B, using a seventy-five kilowatt experimental unit. System A-2 was discarded because of anticipated operating troubles. Costs of A-1 and B are practically identical. Testing showed that precipitation to be best, with most perfect wave form, which can be had with a specially designed motor-generator set and independent of fluctuations in supply-current wave form. Mr. E. P. MATHEWSON said that the following practical points should be discussed: How much humidity is necessary for good precipitation. He cited the experience of one plant where forty per cent is considered best while at Miami the treater on the ore dryers makes an excellent recovery. He also wished information regarding the effect of the nature of solids on the efficiency, saying that zinc oxide is notoriously hard to precipitate. Mr. SOCKETT of Tooele said that converter fume was treated best when sprayed, but that the formation of sulphuric acid was to be avoided. Fume is hardest to precipitate but dust is easy. Mr. RICKETTS said that Miami gets a white precipitate from its converters, recovering all the copper but passing all the zinc oxide. Mr. VIETS said that the Research Corporation's work showed that most careful humidification was necessary on zinc oxide. Mr. SOCKETT of Tooele said that the annual repair cost on the Dwight and Lloyd precipitator is 20 per cent. The net yearly recovery of fume is 38 per cent on the Dwight and Lloyd and 56 per cent on the converter precipitator.

Platinum was first discovered in South America in a section of what is now the Republic of Colombia. Although users of this metal must now depend for their supply practically entirely upon the Colombian mines, since Russian sources of supply have been temporarily abandoned, there appears to be no danger of these resources being exhausted.

French Chemical Industry and the War

"If it were necessary to decide," said a French writer in the *Revue des Deux Mondes* of July 18, "which of all things produced by industry has been most needed and useful to the country since the war began, and without which defeat would have been rapid and inevitable, I should reply without hesitation that it is sulphuric acid."

It has long been an economic maxim, he continued, that the factor which best represents a nation's economic progress is its consumption of sulphuric acid. It is the very life blood of war industries. In the two years preceding 1914, Germany overstocked herself with 600,000 tons of pyrites to make sulphuric acid beyond her normal requirements. These figures may be drawn from her imports from Spain and they furnish an eloquent though silent answer to the attempted German excuses for that nation's great crime. Inasmuch as the war has lasted longer than was the design of the authorities at Berlin they have had recourse to Norwegian pyrites and have cut down the allotment, for the German fertilizer industry normally requires for superphosphates alone some 600,000 tons of this leading chemical product. Bitter complaint has arisen from the farmers because of this restriction in the production of fertilizers.

The reason why sulphuric acid is needed is, among other things, to make guncotton or nitrated wood pulp, for smokeless powder. The cotton or pulp is first treated with nitric and sulphuric acids, after which it is dissolved into a gelatine-like mass to make it insensible to shock and then it is cut into the prismatic disks which constitute smokeless powder. The proportions of nitric to sulphuric acid required to make guncotton are respectively one to three, although no part of the sulphuric acid is present in the final product. The purpose of the sulphuric acid is to combine with the water which is produced by the action of strong nitric acid upon the cotton or cellulose, because as soon as more than a very slight amount of water is present the reaction stops. Something must be added to take up all the water that is formed and an excess of concentrated sulphuric acid will do it, because it is one of the thirstiest bodies known to chemists. But the more it gets the less it wants, so that only a very strong acid will serve the purpose. Ordinary chamber acid such as used in the fertilizer industry will not do at all. What is really needed is oleum or fuming sulphuric acid, and to make this economically the only thing in the world that will answer is platinum.

When the war broke out the monthly production of sulphuric acid in France was only about 5,400 tons per month, mostly at the St. Gobain works, while the German production in times of peace the writer states to be 145,833 tons per month. The present French production, however, for war purposes alone has been increased to over 100,000 tons a month, somewhat approaching the present German production.

Members of the American Chemical Society have been very much interested in this substantial advance in the French manufacture in view of the daily increasing needs for sulphuric acid as the Allied army grows in numbers as well as power.

Starting and Stability Phenomena of Ammonia-Oxidation and Similar Reactions

"Conversion Curve" and "Heat of Reaction Line"—Influence of Temperature, Catalytic Poisons, Thickness and Number of Catalytic Gauzes—Velocity and Concentration of Reacting Gases

By F. G. LILJENROTH

IF THE temperature of the gauze or catalyst of an ammonia-oxidation burner is varied, but all other conditions such as mass flow, gas composition, etc., are maintained constant, the percentage conversion or the degree of reaction will in principle vary according to the curve shown in Fig. 1. At low temperatures there will be practically no nitric oxide formed, but at a certain temperature the conversion will begin to increase very rapidly because the reaction velocity is highly dependent upon the temperature. At still higher temperatures the ammonia will begin to decompose into its elements, and the rate at which the conversion increases will be lower; or in other words, the shape of "conversion curve" will change from convex to concave and at a certain temperature, which I understand is somewhere around 750 deg. C., the conversion will reach a maximum of nearly 100 per cent. Thereafter, the conversion will again decrease and reach a zero value at a fairly high temperature.

The heat of reaction within the temperature limits in question is practically constant and equals about 53,000 gram-calories for each gram-molecule of nitric oxide formed. If we assume a 100 per cent conversion and the presence of, for instance, 9 molecules of air for each molecule of ammonia in the initial gas mixture, then the temperature rise of the gas current due to the heat of reaction will be equal to $\frac{0.95 \times 53{,}000}{7.4\,(9+1)}$ or 675 deg. C., assuming 5 per cent heat-losses by radiation or convection. If the temperature of the ingoing gas is 25 deg. C., then the temperature at the gauze will be 700 deg. C. The figure 7.4 represents the average molecular heat-capacity of the gas mixture at constant pressure. As the gas mixture consists principally of diatomic gases and as the temperature range is comparatively small, it is readily seen that this quantity is practically independent both of the conversion percentage and of the temperature, and that it can with great accuracy be put equal to 7.4.

If the ammonia content in the initial gas mixture is maintained constant, the temperature rise due to the heat of reaction will increase in proportion to the conversion and the temperature of the gauze is graphically represented by the straight line in Fig. 1. This line refers to an initial gas composition of 9 to 1 and to a temperature of the ingoing gas of 25 deg. C. To any other gas composition and to any other temperature of the ingoing gas there corresponds another line. I wish to call particular attention to the fact that in order not to complicate the problem, I have deliberately disregarded the heat of reaction due to the dissociation of ammonia into its elements and other secondary reactions which take place principally at the descending part of the conversion curve. Such a first approximation is permissible because the losses are in any case small.

General Conditions of Stability

The straight line, which will be called the "heat of reaction line," cuts the "conversion curve" ordinarily at two points, *a* and *b*, Fig. 1. It seems, therefore, as if it would be possible to have two points of operation for any burner at a given gas composition and gas flow. But a closer investigation shows that the reaction cannot be maintained at the point *b* because the conditions for stability at this point are not fulfilled. Suppose that the burner is working at this point and that for some reason the temperature decreases by the small amount of *dt*. Then the conversion will decrease to point 1. This decrease will cause the temperature to be lowered still more, to point 2, and this will in turn

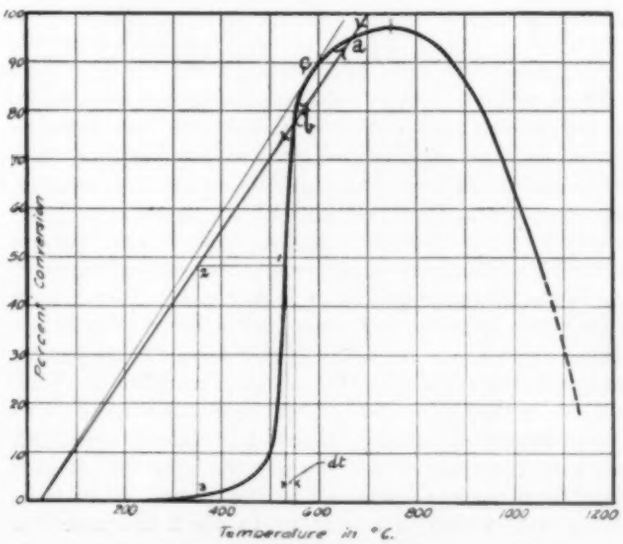


FIG. 1.—CONVERSION CURVE. VELOCITY AND CONCENTRATION OF GAS CONSTANT

cause a new decrease in the conversion, to point 3, and so on. In other words, the burner will go out.

If we assume that for some reason the temperature increases, it will in the same way be found that even in this case we will move away from the point of intersection, which is indicated in the figure by the arrows pointing apart from this point.

If we treat the other point of intersection similarly (point *a*), it will be found that conditions are just opposite. If for some reason we depart from the point, we will immediately be carried back to it, which fact is

indicated by two arrows both pointing toward the point. Point *b* is therefore an unstable location while point *a* is a stable one. As can easily be understood, this characteristic difference depends upon the manner in which the heat of reaction line cuts the conversion curve. In

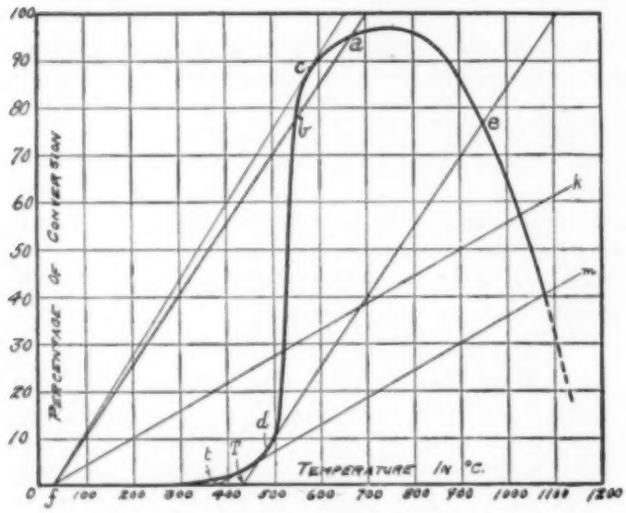


FIG. 2.—CONVERSION AT IGNITION POINT

order to obtain stability the heat of reaction line must cut the conversion curve from below, and from this it follows that the part of the conversion curve to the left of the tangential point *c* is unstable, but that the part to the right is stable. It will also be understood that the stability or instability increases with increase in the size of the angle at which the line and the curve cut each other.

Starting of the Reaction

From what has been said regarding the unstability of the point *b*, we can now understand that the ammonia-oxidation process is not self-starting or self-exciting, but that the gas, in order that the reaction may be started, must be heated by a flame or by electricity to at least such a temperature *T* that the resulting line becomes a tangent to the ascending part of the conversion curve, as is shown in Fig. 2. In such a case the reaction will start and after a short time arrive at point *e*. After this the starting flame can be removed and the reaction will move to point *a*. This not only makes it very clear whether and why the ammonia oxidation or any other continuously operated catalytic reaction is self-starting or not, but it also gives us a method by which to predetermine the temperature *T* which is necessary to start the reaction. This "ignition-temperature," as seen from Fig. 2, is always much lower than the reaction-temperature; or, in other words, it is not necessary to heat the reaction to its full temperature but only to help it overcome the obstacle formed by the ascending part of the curve. When this obstacle has been overcome, the reaction will take care of the rest itself and work up to the full temperature.

The temperature necessary to start the reaction can be decreased by using a gas mixture richer in ammonia, because the position of the heat of reaction line will be lowered. This is indicated by the lines *fk* and *tm* in Fig. 2. I understand that this method of starting is really used in some oxidation plants.

The shape of the conversion curve of all continuously operated exothermic catalytic reactions is in principle the same as that of the ammonia oxidation. It ascends at first, due to the fact that the reaction velocity increases with the temperature, but as it is limited by the always descending equilibrium curve, it must sooner or later reach a maximum; thereafter it begins to descend. (In the ammonia-oxidation process the descent begins earlier than would be expected from the equilibrium curve,[1] this being due to the fact that another reaction, the decomposition of ammonia into its elements, begins to take place at higher temperatures beside the oxidation reaction.) The possibility that there are continuous exothermic reactions which are self-starting is therefore not excluded, because the only condition that needs to be fulfilled is the necessity of having the conversion curve from the beginning lie above the heat of reaction line.

An example of a self-starting reaction is offered by the long known fact that the hydrogen-air or hydrogen-oxygen flame can be ignited by means of a small piece of platinum sponge. This is represented in principle in Fig. 3. The lower curve corresponds to the non-catalytic reaction which, as may be noted, is not self-starting. By using a strong catalyst the curve is raised so that from room temperature and up it lies above the heat of reaction line, this being the general condition for self-excitation. The temperature of the platinum sponge will consequently increase to the point *a* which is always above the ignition temperature *T* of the non-catalytic reaction. The fact that a hydrogen flame can be ignited by means of spongy platinum induced inventors to try the same experiment with ordinary coal gas. It was found, however, that the platinum sponge began to glow but that the gas would not ignite. This

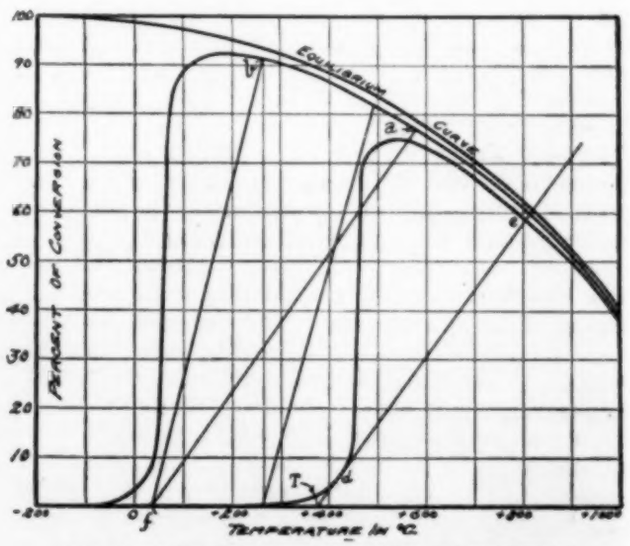


FIG. 3.—COVERSION. SPONTANEOUS IGNITION

was explained by saying that coal gas is not so inflammable as hydrogen and that the temperature of the platinum sponge was too low.

How can this fact now be brought into agreement with our theory? The explanation is very simple. The

[1] As can easily be shown by Nernst's "New Theorem," that the ammonia-nitric oxide equilibrium is, within the temperature limits in question, practically constant and above 99.99 per cent. For obvious reasons this equilibrium cannot be determined experimentally.

radiation of the ignition system is very large, even if the radiation of the whole system is zero, and to the ignition-conversion curve (the upper curve) belongs, therefore, not the same heat of reaction line as to the main conversion curve, but a line much further to the left. If the point of intersection *b* between this line and the catalytic conversion curve corresponds to a lower temperature than *T*, it can be seen that the platinum sponge will begin to develop heat without being able to ignite the gas. In order to raise the temperature to *T* we can place two pieces of platinum sponge in series so that the gas arrives at the second one, preheated to such a temperature that the final temperature is higher than *T*. If it is not enough with two, we can put three pieces in series.

Numerous other arrangements have been proposed in order to ignite the coal gas flame by means of platinum sponge, and the reasons why one arrangement works better than another, or why it does not work at all, are very vaguely stated in the literature, but with this explanation become extremely clear and simple.

Determination of the Conversion Curve

The heat of reaction line can be very easily determined both theoretically and experimentally, but the conversion curve can be determined only by experiments. Points on the descending part to the right of point *a* (see Fig. 2) can be determined by preheating the ingoing gas to different temperatures; at the same time we can also obtain the part of the curve which is left of point *d*. The part of the curve between *a* and *c* can be determined by increasing the heat losses, for instance by water cooling the burner. The unstable part of the curve between points *c* and *d* cannot be determined directly, but it can be determined indirectly by extending the stable parts of the curve and connecting points *c* and *d* in an intelligent way. In case the temperature, caused by the heat of reaction, is small, which for instance is the case in the Haber process (due to both the low heat of reaction and the low conversion obtained), the unstable part of the conversion curve will be very short. Practically the whole conversion curve can be determined therefore simply by cutting out the heat exchanger and heating the gas electrically, keeping a constant current or voltage.

Practical Conditions of Stability

It has been noted that the only condition which needs to be fulfilled in order to keep a reaction going, when it once has been started, is the necessity of having the heat of reaction line cut the conversion curve from below. We would expect therefore that it should be possible to work at the maximum point of the conversion curve because this point is on the right side of point *c* where the stability zone begins (Fig. 2). This also is possible under ideal conditions, that is, if gas composition, gas flow etc. are maintained absolutely constant. In practice, however, there will always be small variations in gas composition and gas velocity which cause the heat of reaction line and the conversion curve to change their positions continuously. If, for instance, the ammonia content in the ingoing gas for some reason decreases, the heat of reaction line will turn counterclockwise around its point *f* on the abscissa. If it turns past the tangential position *c* and remains there long enough for the gauze to cool below the ignition temperature, the burner will go out. This time, which by the way can be calculated exactly if the conversion curve is known, is very short because the gauze is rapidly cooled by the incoming cold gas mixture, the heat capacity of the gauze and the walls being comparatively small.

The conversion curve is also affected by the gas composition and besides that by the gas velocity. As already noted, both of these quantities vary in practice a few per cent and consequently the heat of reaction line and the conversion curve will both oscillate around an average position. Ample margin between points *a* and *c* must therefore be provided. If the top of the conversion curve is sharp, it will be impossible to work at a maximum efficiency, because we have to move the working point further to the right side, sacrificing efficiency in order to obtain stability. This also implies higher temperature. If the conversion curve is very flat, which seems to be the case in the ammonia-oxidation reaction, it will be possible to work not only at the top point but even a little to the left of it. As far as I understand, this is really what is done in the ammonia-oxidation process if no heat exchanger nor any additional heat above the heat of reaction is used. A decrease in the radiation losses will consequently improve not only the stability but also the efficiency. If the radiation is decreased as much as possible, and if we are still on the ascending part of the conversion curve, the only way to reach the top is to use a heat exchanger or some additional heat. If we are very near the top it will probably not pay to go into this complication.

The margin of stability must be greater, the greater the variations in initial gas strength and gas velocity. It is therefore of importance to keep the motors at a constant speed driving the ammonia and air-blowers and in general to keep the gas current as steady as possible. Of how great importance this is can be determined only if conversion curves of a number of different gas compositions and different gas velocities are known.

Influence of Catalytic Poisons Upon Stability

If occasionally the steadily flowing gas current should carry along some foreign gas, we would have the same kind of disturbance as we would if the ammonia content varied. If the foreign gas or matter is not indifferent, or if it acts as a poison to the catalyst, the disturbances may be still worse. In such cases still more margin must be provided; that is, we must work further to the right of the maximum point (see Fig. 4) which means a higher temperature and a decrease in the conversion from point *a* to, for instance, point *g*. We must now remember that the conversion curves always refer to absolutely pure gas mixtures and we will have therefore in addition to this decrease another reduction depending upon the frequency, the nature, and the duration of the impurities.

This can be stated also in another way. In a plant where such impurities are likely to appear, we must safeguard ourselves against the burner going out by working with more ample margin; that is, even if for some length of time the gas happens to be pure, we will still have a lower efficiency than in a plant where we

know the gas mixture to be constantly pure. When the impurities appear, however, we will have an additional loss, but the loss cannot, of course, be precalculated but only estimated from practical experience.

The first kind of loss can be measured exactly by running the burner with pure ammonia at the same gas flow and gas strength as when the impure ammonia is used. It can also be determined from the conversion

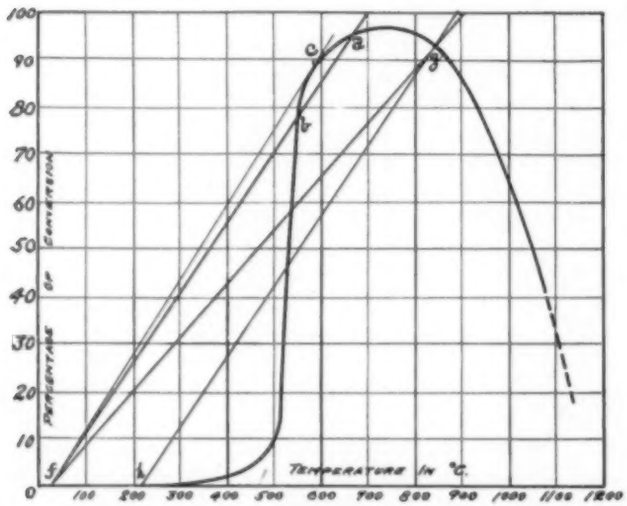


FIG. 4.—CONVERSION. CATALYTIC POISONS

curve in the following way: Suppose the gauze is heated by electrical energy but that no heat exchanger is used, and furthermore that the electrical power consumed is equal to 0.03 kw.-yr. per ton of HNO_3 which equals $\frac{0.03 \times 8760 \times 3600}{4.2}$ kg. cal. per ton of HNO_3, which in turn equals $\frac{0.03 \times 8760 \times 3600}{4.2} \times \frac{63}{1000}$ or 14,000 kg. cal. per kg. mol. of NH_3.

The temperature rise due to the electrical heating alone will hence be $\frac{14{,}000}{7.4(9+1)}$ or 190 deg. C. If this temperature is added to the plain heat of reaction line, we get a line (*hg*, Fig. 4) beginning at 190 + 25 deg. C., and ending at 700 + 190 deg. C. This line cuts the conversion curve at point *g* and we can thus find the conversion and the loss. The temperature rise of 190 deg. C., due to the electrical heating, could also have been determined experimentally by running the burner with a normal gas flow and a normal electrical energy but without igniting the burner. This test can be run just as well with ordinary air as with ammonia-air mixture, thereby saving the ammonia.

In the ammonia-oxidation process it happens that if the radiation losses are small, the reaction itself develops just about enough heat to give the proper temperature, or in other words, the heat of reaction line cuts the best conversion curve in the neighborhood of the top just far enough to the right of the point *c* to secure stability, assuming that pure raw materials (for instance, high-grade coke-oven aqua ammonia) are used. In case the ammonia contains impurities, poisonous to the catalyst, as seems to be the case with cyanamide-ammonia, higher temperatures must be employed in order to secure stability, as has been shown above. This can be done either by using a heat exchanger, line *fg* (Fig. 4), or by supplying some additional heat, line *hg* (Fig. 4). As there is always a time lag in the action of any heat exchanger the temperature will not decrease instantaneously as the impurities come along. If, therefore, the impurities are of short duration with fairly long intervals, the use of a heat exchanger may be preferable to the plain heat of reaction method, assuming that it could be employed here. If, on the other hand, the impurity periods are long and the intervals short, it will be understood that the heat exchanger is inferior to the plain heat of reaction method.

This is a true analogy to the action of a flywheel in connection, for instance, with a rolling mill. In a blooming mill very heavy flywheels are used, whereas in a wire mill the rotating masses must be made as small as possible. The employment of additional heat, either by preheating the gases in a fuel-heated furnace or by electrically heating the gauze, gives the most stable conditions, especially if the external heat alone gives a temperature which is higher than the ignition temperature, in which case the burner ignites itself again as soon as the impurities have passed, supposing that these were of such magnitude so as to cause the burner to go out. It is not very probable that this is the case in any ammonia burner because it would mean unnecessarily high stability, very high temperature and very low efficiency. On the contrary, even electrically or fuel-heated burners must be ignited by a flame or coil or by increasing the current in the gauze above the normal value.

In regard to fuel heating versus direct electrical heating of the gauze, we would expect one method to be just as good as the other, assuming that the electric current has no direct activating influence on the platinum.

Such an influence is very improbable in view of the excellent results obtained without the use of electric heating; this has probably been adhered to as an easy way of explaining the fact that the direct electric heating gives higher stability than if the same amount of additional heat is supplied outside the gauze. The following explanation seems to me much more plausible. The electrical resistance of platinum as well as of other metals increases with the temperature. At 700 deg. C. it is about 3 to 4 times as high as at 0 deg. If, therefore, due to a weakening of the gas strength or to poisonous impurities, the gauze begins to cool and blacken, the current flowing through it will immediately increase in the same proportion as the resistance decreases. Furthermore, as the heat developed is proportional to the square of the current times the resistance (I^2R), it follows that the electric energy converted into heat will increase when the temperature decreases. This phenomenon is the more marked, the less external electric resistance there is connected in series with the gauze. If the external resistance is equal to or higher than the internal, the reverse condition will prevail and it may be necessary to use a costly automatic constant current regulator. If none or only a very small amount of external resistance is used, it is not only useless but detrimental to use automatic regulation. Further investigation of this problem leads to very interesting conclusions in regard to the manufacture of the gauze and the arrangement of the electrical heating and starting. Besides this "electrical influence," the electric heating has the advantage of having the heat supplied directly within the metal,

whereas with outside heating the heat must first travel from the gas to the metal.

It has been noted that when using even pure raw materials ample margin of stability must be provided to take care of the oscillations in the heat of reaction line and in the conversion curve, because of variations in the gas strength and gas velocity. We will discuss this matter more in detail.

Influence of Gas Velocity

The gas velocity has no influence upon the heat of reaction line but affects the conversion curve in the following manner: At low temperatures, where practically no ammonia dissociation takes place, the conversion is higher the lower the gas velocity, because the time of reaction is longer and the reaction consequently comes closer to equilibrium. At higher temperatures this increase is probably more than counterbalanced by the increase in ammonia dissociation due to the same conditions as the increase in the ammonia oxidation. If, therefore, the velocity corresponding to our working curve is called 100 per cent, the curves corresponding to 90 per cent and 110 per cent will probably have the positions and shapes indicated in Fig. 5.

It can be easily seen why the stability decreases when the gas velocity increases and why the flame can be "blown out." If the velocity decreases, the stability will at first increase, but probably decrease later on. If this were not the case, it would be possible to get the reaction to start without the use of an ignition flame simply by increasing the gas velocity very slowly from zero up.

As seen, I have shown the 110 per cent curve having a higher peak than the 100 per cent curve. If this really is the case, there is a double reason why we should increase the working velocity and at the same time increase the temperature by, for instance, introducing a

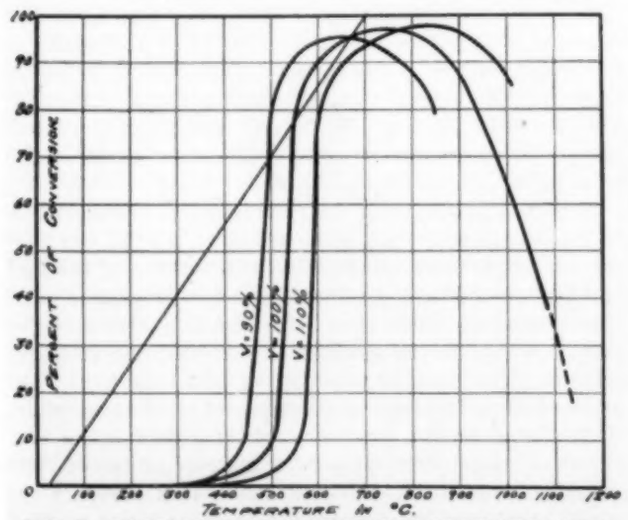


FIG. 5.—VARIATION OF CONVERSION WITH VELOCITY

heat exchanger. The output of the plant will increase not only in proportion to the gas velocity but also in proportion to the conversion. If we increase only the gas velocity without changing the heat of reaction line the conversion will go down, probably more rapidly than the velocity will go up, resulting in a lower output instead of a higher one. Besides this the stability will rapidly decrease, as already noted.

Influence of Gas Strength

The influence of the variations in the ammonia content of the gas mixture upon the stability is more complicated because such variations influence both the heat of reaction line and the conversion curve. This first influence is very simple; the heat of reaction temperature at a certain conversion increases in proportion to

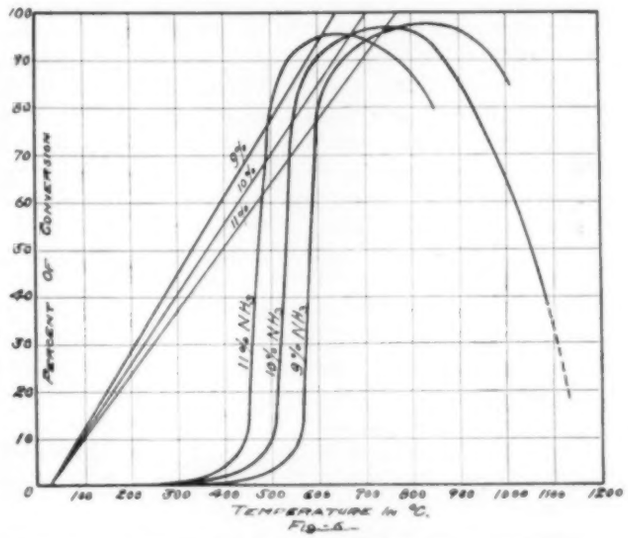


FIG. 6.—VARIATION OF CONVERSION WITH CONCENTRATION

the ammonia content (see Fig. 6). The latter influence, however, is very complicated and the only guess I would like to make is that at lower temperatures the conversion increases with the gas strength. If the curves for different gas strengths appear as is indicated in Fig. 6, we can understand that the stability will be greatly increased if the gas strength increases, because the heat of reaction line moves to the right and the conversion curve to the left. Conversely, the stability will rapidly decrease when the gas strength is weakened.

What has been said regarding the possibility of improving the process by decreasing the time of reaction and by introducing at the same time a heat exchanger can also be applied here if we substitute gas strength for time of reaction and assume that the conversion curve in principle moves as indicated in Fig. 6.

If the curve, on the contrary, moves to the right instead of to the left when the gas strength increases, the stability will be practically unaffected by changes in the gas strength, because the heat of reaction line will oscillate synchronously with the conversion curve.

Oxygen Instead of Air

If the ammonia gas is mixed with oxygen instead of with air we must for economical reasons work with a very high ammonia content in the ingoing gas. The heat of reaction line will consequently turn clockwise a very big angle, giving a temperature several times higher than that when using air at the same conversion. If the conversion curve has the shape assumed and if this shape is not materially changed by the exclusion of the nitrogen, the result will be a higher temperature and stability, but a lower efficiency than if air were used. This can, of course, be corrected by water-cooling the gauze, but as when using air, the stability

is sufficient and the efficiency above 95 per cent, the use of oxygen is not justified, at least not for the sake of a possible increase of efficiency.

Thickness and Number of Gauzes

In view of what has been said, the influence of the thickness and number of gauzes becomes very simple and clear.

The thickness of the gauze affects the conditions only in the matter of reaction time, assuming that the effective contact surface is changing in the same proportion as the contact time. A change of the thickness of the gauze, therefore, acts in the same way as a change in the gas flow. The result will be the same whether we double the gas flow, or decrease the thickness of the gauze to one-half. If the gas flow and the thickness of the gauze are both increased or both decreased in the same proportion, the conditions will not be changed at all.

The influence of the number of gauzes is the same as the influence of the thickness of the gauze, but only if the gauzes are placed very near each other and in good metallic connection so that the temperature is always the same in all the gauzes.

The problem is quite different and much more complicated if the thermal interconnection of the gauzes is incomplete. In order not to make the problem too complicated, I will assume the extreme condition that the gauzes are completely independent of each other thermally. This means that no other heat exchange can take place between the gauzes than by the way of the gas current. Let us assume that we have a burner working with, for instance, two gauzes, placed in complete contact with each other. If, now, the two gauzes are moved apart and thermally isolated from each other so that no heat can be radiated or conducted between them, the first gauze will act as if the velocity had been increased to double its value. If, before moving the gauzes apart, we were working in the neighborhood of the top of the conversion curve, the burner would probably go out, or at least work with less margin of stability. If the latter is the case, the temperature will change somewhat, but the efficiency will still be in the neighborhood of its maximum value, leaving practically nothing for the second gauze to do. If the burner goes out we have to use a heat exchanger or apply electric heating, or we have to decrease the gas flow in order to re-establish the stability. If we apply any of these means just sufficiently to get the same stability and efficiency as before, there will again be practically no work left to the second gauze. But even if we use these means in excess, or in other words, when we work far down on the descending part of the conversion curve, the second gauze will have very little to do because the losses in the first gauze are principally caused by ammonia decomposition. Only in case we work far down on the ascending part of the conversion curve would there be some ammonia left for the second gauze, but as previously shown, the ascending part of the conversion curve is practically all within the unstable zone. If this could in some way be made stable, the gas leaving the first gauze would have to be water-cooled before it entered the second gauze in order to prevent the latter from reaching too high a temperature and too low a yield.

In case platinum should become very scarce, such an arrangement might be advantageously used, in that a cheap low-grade catalyst could be substituted for the first gauze and the succeeding platinum gauze made to do the final work analogous to the method frequently used in the catalytic-sulphuric-acid process. But the first stage of the conversion must be worked in such a way that the greater losses will consist principally of ammonia going unchanged through the catalyst; that is, we must work in the unstable zone, which might not be absolutely impossible.

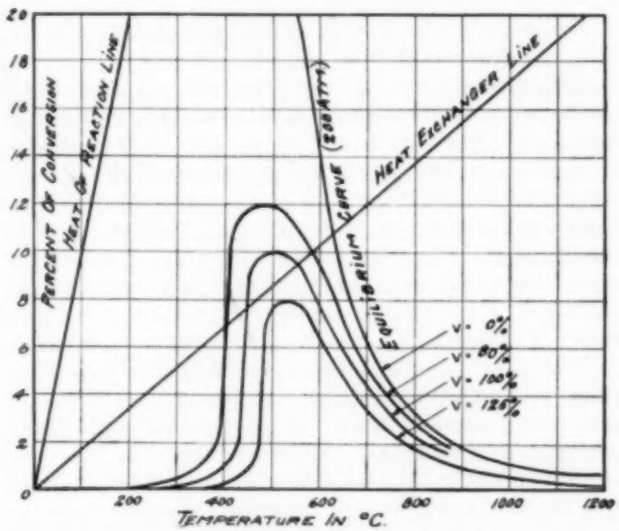


FIG. 7.—VARIATION OF CONVERSION WITH LOW GAS VELOCITIES

Synthetic-Ammonia Process

Here the conditions are still simpler because no disturbing reactions take place. The conversion curve has the same shape as in the ammonia-oxidation process. It first rises rapidly, reaches a maximum, and then begins to decrease because the conversion is limited by the falling equilibrium curve. If the gas velocity is decreased, the entire curve moves upward, and vice versa if the velocity is increased (see Fig. 7).

If seems, therefore, as if we ought to work with a very low gas velocity. This would be true if the conversion were the deciding factor, but because of the fact that the gas mixture is recirculated, the conversion is of only secondary importance. The deciding factor is the output, which is the product of gas velocity and conversion. The working point is therefore the top of the conversion curve at which this product is at a maximum. If, however, proper consideration is given to the cost of the ammonia removal and to the cost of the electric power, a new curve somewhat above this curve is obtained. Anyhow, we will assume that the curve marked velocity = 100 per cent is the most economical curve.

The heat of reaction is equal to about 14,500 g. cal. per g. mol. of ammonia at the temperatures in question. For each per cent of conversion, the corresponding temperature rise is thus equal to $\frac{14{,}500}{7.25 \times 2 \times 100}$ or about 10 deg. C.

The corresponding heat of reaction line never cuts the conversion curve, which means that in the synthetic-

ammonia process, contrary to what is the case in the ammonia-oxidation process, a heat exchanger must always be used. Besides the heat exchanger, there must usually be supplied some additional (frequently electric) heat. The reason for this is that the heat of reaction is as a rule insufficient to cover the radiation loss and to create the temperature difference which is needed to keep the size of the heat exchanger within reasonable limits. If a high pressure and a good catalyst are used, the conversion will be higher, the heat of reaction will be sufficient, and no electric or other heat needs to be supplied from without except during the starting period, as can be seen from Fig. 7. The amount of electric power necessary for starting can easily be calculated if the conversion curve and the gas velocity are known. This power can be decreased if the gas velocity is lowered during the starting period, as seen from Fig. 7. It can also be noted that if the gas velocity is increased, the stability will decrease and vice versa. Ample margin of stability, therefore, must be provided; if the gas velocity is increased too much, the flame can be "blown out."

If no electric heat is used, the influence of the gas velocity on the heat of reaction line ought to be very small, because at the high mass flow per square foot here prevalent, the heat transfer (B.t.u. per sq.ft. per hour) of the heat exchanger walls is practically proportional to the gas velocity. The heat transfer is equal to the sum of two quantities, one of which is constant and the other proportional to the mass flow per square foot. If the mass flow per square foot is very large, as is the case here due to the high compression (100 to 200 atm. pressure) the constant quantity is negligible. If, after all, there is an influence depending upon a faulty design of the heat exchanger, this influence works to turn the heat of reaction line counter-clockwise when the velocity increases. As shown above, the conversion curve moves in the opposite direction. In such a case a still greater margin must be provided.

If electric heating is used but no heat exchanger, the resulting line is parallel to the heat of reaction line proper, and if a heat exchanger[2] but no electric heating is used the resulting line goes through the origin. Consequently, if both electric heating and a heat converter are used simultaneously, the resulting line is the sum of these two factors. If the gas velocity increases, the constant part of the temperature corresponding to the electric power decreases inversely as the gas velocity. Strange as it may sound, the reaction is therefore more sensitive for increases in gas velocity with electric heating than with only a heat exchanger.

The gas composition has no influence at all upon the heat of reaction line and practically no influence upon the conversion curve, which can be understood from the following. The conversion corresponding to equilibrium is approximately proportional to $\sqrt{N.H^3}$, where H is the volume of hydrogen and N the volume of nitrogen present in a certain amount, say four volumes, of the mixture. If we are far from the point of equilibrium, the decomposition velocity is negligible and the conversion is consequently in proportion to H^3N. The following tabulation shows that both $H^3 \times N$ and $\sqrt{H^3 \times N}$ are practically constants within wide limits:

H	N	$H^3 \times N$	$\sqrt{H^3 \times N}$
3.2	0.8	26.3	5.14
3.1	0.9	26.8	5.17
3.0	1.0	27.0	5.2
2.9	1.1	26.8	5.17
2.8	1.2	26.3	5.14

The gas composition, therefore, has practically no influence upon the stability.

Conclusion

In the same manner, many interesting conclusions can be drawn in regard to the starting and stability of other continuously working catalytic and exothermic reactions as, for instance, the sulphuric-acid process, the conversion of $CO + H_2O$ to $CO_2 + H_2$, the conversion of NO to NO_2 etc.

The method can probably be advantageously applied also to non-catalytic, exothermic, continuous or discontinuous (explosive) reactions, although the conditions here are much more complicated because the time of reaction in the first case is not an arbitrary constant but a function of the temperature, the gas velocity, the radiation etc. In the second case, the time of reaction is in itself an independent variable in addition to the independent variable which we already have, namely, the temperature.

It would be beyond the scope of this article to go into these questions, but I hope that the above examples have been sufficient to demonstrate the usefulness of the method of investigation set forth. It not only explains in a very simple manner the starting and stability phenomena and the influence of catalytic poisons on the stability, but it might also be useful for the further studying and improving of ammonia oxidation and similar processes. It is therefore desirable that pure raw material conversion curves be determined for different gas strengths and gas velocities, both for ammonia-air and ammonia-oxygen mixtures. If such curves were available, it would be possible to adjust or design a burner for a maximum commercial efficiency, giving proper consideration to conversion efficiency, output etc. This applies also to other processes.

Finally, I wish to point out that this article refers only to the method of investigation and not to any specific data. The shape of the curves and the figures given should be considered only as examples.

Washington, D. C.

[2] A closer investigation shows that the most economical heat exchanger has such a high mass flow that the constant term is negligible.

Treatment of Caustic Soda Burns

As the workmen in the kettle room of the caustic soda works are exposed to painful burns at the syphon line faucet while filling the drums as well as in handling the containers of the molten caustic, some emergency aid should be immediately available for treatments. Mr. M. Firsinger read a paper before the National Safety Convention at New York, in which he recommended a two per cent solution of acetic acid as an acid wash, followed by an oil dressing. Absorbent cotton should not be placed in immediate contact with the wound, but can be used on top of a lint-free pad saturated with vaseline, carron oil or other air excluder. Perhaps aluminium acetate would be a preferable form of neutralizer—especially in cases involving the eyes and lips. Aluminium soap would also be preferable to the lime water emulsions.

Slag Control in the Iron Blast-Furnace by Means of Slag Viscosity Tables

Application to Blast Furnace Operation of Viscosity Data Obtained in Former Investigation by Bureau of Mines—Method of Using Slag Viscosity Tables—Examples Demonstrating Their Application

BY ALEX L. FEILD
Research Physical Chemist, National Carbon Co., Inc., Cleveland, Ohio.

THERE has not been available until recently experimental data which were of any great assistance to the blast-furnace operator in his control of slag composition. The Bureau of Mines has completed an extensive investigation of the properties of slags at high temperatures over a wide range of compositions. The results of this work have been published as Bureau of Mines *Technical Papers* 157, 187, and 189, and also in several technical journals.[1]

By means of the viscosity data obtained in the investigation it is possible to decide upon the proper slag composition by a procedure which has as its basis a series of experimental measurements conducted with care and with due regard to the needs of the case.

Technical Paper 187, "Slag Viscosity Tables for Blast-Furnace Work," contains the complete slag tables and is written particularly for iron metallurgists. *Technical Paper* 157, "A Method for Measuring the Viscosity of Blast-Furnace Slag at High Temperatures," was the first preliminary report and contains a description of the apparatus and methods of measurement, together with viscosity measurements on a limited number of slags.[2] *Technical Paper* 189, "Temperature-Viscosity Relations in the Ternary System CaO-Al_2O_3-SiO_2," contains the more scientific results of the investigation and in addition a description of the improvements made in experimental technique since the appearance of the preliminary paper.

PURPOSE OF THE PRESENT PAPER

In former publications, purporting to be nothing more than a permanent record of experimental measurements, it was advisable to give only a few brief suggestions as to the actual application of the data to blast-furnace operation.

It is the purpose of the present paper to indicate in some detail the most obvious method of using the slag viscosity tables in slag control, and by actual illustrative examples to demonstrate the method. It is not considered necessary to reproduce the slag tables since the publication in which they appear can be readily obtained by any one desiring it.

Beforehand, it may be well to make clear exactly what significance is attached to the term "viscosity" and to point out how this property in the case of a slag is of primary importance in determining the economy of operation of the blast-furnace. This last matter is of unusual importance at the present time. Whether or not there will be sufficient coke at the blast-furnaces during the winter of 1918-1919 is a matter of grave importance, but the most immediate duty of every blast-furnace superintendent is to make a maximum production of pig-iron with a minimum fuel consumption.

VISCOSITY

All bodies may be divided into three classes—gaseous, liquid and solid. For our present purpose we will confine our attention to the solid and liquid states of matter. Here we will take our stand with the physicist rather than the chemist, and simply define a liquid as any substance other than a gas, which if left to itself will assume in the course of time the shape of a vessel in which it is placed; and a solid as a body which retains its own shape under the action of small forces. According to this definition a piece of slag at room temperature is a solid regardless of whether it is glassy, or "lean," or whether it is crystalline, or "limey." On the other hand, a slag is a liquid, whether the entire mass is homogeneous or contains numerous small crystals scattered through its interior, provided it will move, however slowly, along an inclined runner under the action of gravity. In all these cases, the chemist makes a number of distinctions in his definitions, well-suited for his own needs but of no value in the present case.

Having fixed in mind exactly what is meant by "solid" and "liquid," let us give our attention to the definition of viscosity. The viscosity of any substance is proportional directly to the force required to rotate a cylindrical rod of given dimensions with unit angular velocity when immersed in the liquid. As every one knows it takes a greater effort or force to twist a pole around in a barrel of pitch than it does in a barrel of water. If it takes a thousand times as much force in the former case than in the latter, the viscosity of the pitch would be a thousand times as great as that of water. In the absolute or C.G.S. system of units used in the slag tables (Technical Paper 187) it so happens that the viscosity of water at 20 deg. C. is almost exactly 0.01. Hence the viscosity of the pitch would be equal to 1000×0.01, or 10 C.G.S. units.

Another way to visualize the property of viscosity is to recall that the length of time it takes a liquid of given volume to flow through a small capillary tube, under a constant pressure-head, is directly proportional to its viscosity.

While all liquids have a definite viscosity which can be measured, the viscosity of a solid is, of course, in-

[1] *Bulletin* A. I. M. E., Feb. 1917, pp. 307-32; Dec. 1917, pp. 2030-36; 2037-43.
Transactions Faraday Society, vol. 13, Pt. I, pp. 1-33 (1917).
Chemical News, vol. 117, pp. 13-16, 27-29, 40-41, 54-56, 64-67 (1918).

[2] See also above.

finite. We may therefore define, a solid as a body the viscosity of which is infinite, and a liquid as a body, other than a gas, the viscosity of which is finite or measurable.

I have found that there exists in the minds of some a strange confusion regarding the meaning of viscosity. This is probably due to the ordinary meaning of the word "viscous" as used in conversation. Such a one is certain that molasses is "viscous" and has "viscosity"; but is at a loss when asked to compare it with water or ice, and may conclude that neither ice nor water have any viscosity. As has been stated, the viscosity of water at 20 deg. C. is equal to 0.01, while the viscosity of ice is infinitely great, i.e. greater than any value which we could assign to it.[3]

Just as the reciprocal of density is specific volume, so the reciprocal of vicosity is "fluidity." In other words, fluidity, as physically defined, is numerically equal to 1 divided by the viscosity. Accordingly, the fluidity of water at 20 deg. C. is $\frac{1}{0.01}$ or 100; while the fluidity of the pitch would be $\frac{1}{10}$, or 0.1. It is obvious that the fluidity of a solid is equal to $\frac{1}{\text{infinity}}$, or zero. Just as there are no bodies with zero viscosity, so there are no bodies with infinite fluidity. Values expressed in terms of fluidity instead of viscosity offer certain advantages when plotted against temperature, forming very nearly a straight line function. However, it would appear that viscosity is actually the measurable property of a body, and for this and other reasons it was used exclusively in the slag tables.

Change of Viscosity With Temperature

The viscosity of practically all bodies decreases with rising temperature, and this rule is true without exception in the case of silicates and mixtures of silicates. The rate of change is most rapid just at the melting point. Above the melting point, i.e., the temperature at which the slag passes from the solid to the liquid state, some slags decrease in viscosity much more rapidly than others. The rate of change of viscosity at any given temperature is known as the temperature coefficient of viscosity. If we plot the temperature of the slag as abscissae and the viscosity as ordinates, we get in the case of a slag such a curve as is shown in Fig. 1, known as a temperature-viscosity curve. The line *AB* which the upper portion of the curve approaches asymptotically cuts the X-axis at a point corresponding to the melting point of the slag, since at that temperature the viscosity becomes infinite.

Even at temperatures well above the melting point the change of viscosity of practically all bodies is much greater than is ordinarily supposed. For instance, water just above the freezing point is about 3 times as viscous as water at 100 deg., the rate of change being about as rapid above 50 deg. as below it.

Dependence of Temperature-Viscosity Relations on Slag Composition

It will be sufficient here to state that the shape and position of the temperature-viscosity curve with respect to the axes is entirely dependent on the chemical composition of the slag as shown by analysis. Sometimes a relatively minor change in the percentage of one or more of the major constituents—lime, alumina and silica—causes a great change in the temperature-viscosity relations as shown by the temperature-viscosity curve. This is due to the existence of undissociated molecular compounds of lime, alumina and silica in the molten state,[4] with fields of stability which are those indicated by the temperature-concentration diagram of this ternary system as given by Rankin and Wright.[5] If, for instance, we gradually increase the lime content of a slag the temperature-viscosity relations do not undergo a continuous, gradual change in the same direction, but display well-marked maxima and minima.

Contrary to the usual belief, changes in the percentages of the minor constituents of a slag—MgO, MnO,

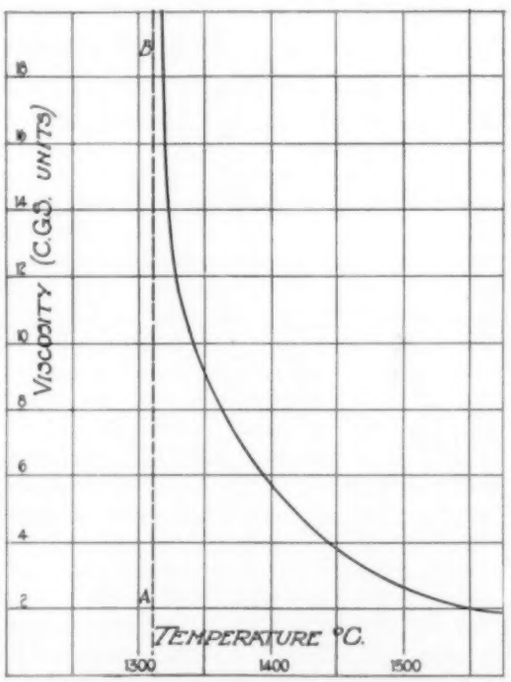


FIG. 1.—VARIATIONS OF VISCOSITY WITH TEMPERATURE

FeO, TiO_2, Na_2O and K_2O—have a practically negligible effect on the temperature-viscosity relations provided the percentages of the major constituents—CaO, Al_2O_3, and SiO_2—do not change relatively to one another. In the slag investigations it was found that the temperature-viscosity relations of all slags in which the sum of the percentages of the minor constituents did not exceed 14 per cent were determined only by the relative percentages of lime, alumina and silica. This condition is met by practically all slags in which the percentage of MgO, the most important minor constituent, does not exceed about 8 per cent.

Sulphur in iron blast-furnace slags is present as calcium sulphide, CaS, and should be treated simply as one of the minor constituents. In slag analysis, sulphur should be reported as calcium sulphide, CaS.

The small effect exerted by the minor constituents on the slag properties is due to the fact that they are present in the slag in the state of solution, retaining

[3]For convenience in presentation the case of plastic solids, flow under shears greater than a critical value, etc., are not taken into consideration. For further information on these points see Bureau of Mines *Technical Paper* 189, pp. 10-12.

[4]For the evidence pointing to the existence of silicate compounds in the liquid state, see *Technical Paper* 189, pp. 7-10, 21-23, 29-33.

[5]G. A. Rankin and F. E. Wright: "Ternary System CaO-Al_2O_3-SiO_2." *American Journal of Science*, ser. 4, vol. 39, pp. 1-79 (1916); see also *Technical Paper* 189, p. 6, Fig. 1, where the essential features of the diagram are reproduced.

their oxide or sulphide structure. On the other hand, lime, alumina and silica are not present in the molten slag as a mutual solution of the oxides of calcium, aluminium and silicon, but as more or less complex silicates and alumino-silicates of lime. The identity and relative proportions of these silicates and alumino-silicates which are present in a slag can be readily calculated from the ternary diagram of Rankin and Wright, although, as has been previously pointed out, these investigators were not aware at that time that their data were applicable at temperatures above the saturation temperature of the melt. The presence of the minor constituents does not make itself felt appreciably until the concentration of one of them becomes great enough to result in the introduction of a new molecular species into the ternary system, changing it thereby to a quarternary system.

Behavior of the Slag in the Furnace

The blast-furnace is a furnace which operates on a regenerative principle, the highly heated gases of combustion passing up through the descending charge and pre-heating it. These gases of combustion, or flue-gases, are further used to pre-heat the air supplied for combustion, since they are high in carbon monoxide and fortunately have a fairly good calorific value.

The conditions are therefore such that if the furnace shaft were filled with coke alone the temperature would within a short while reach such a high value that the entire refractory lining of the furnace would be fused. However, if the coke is mixed with just the proper amount of material—the slag ingredients—which melts, say, at 1450 deg. and runs down into the hearth and thence through the iron notch to the outside, there will result a slow downward movement of the charge with the coke burning away at the same rate that the slag (and also molten iron) runs down into the hearth. This downward movement of the charge, initially at atmospheric temperature, is the factor which prevents the attainment of extreme temperatures in the smelting zone. It is seen then that the temperature-viscosity relations of the slag (which includes the phenomenon of melting) determines the working temperature of the blast-furnace. Like all industrial furnaces, the blast-furnace consumes an amount of fuel which increases rapidly as the furnace temperature is raised. It is upon this point that the importance of slag control as related to fuel economy hinges, and for this reason the slag problem is essentially a fuel problem.

The ternary eutectic of lowest melting point in the lime-alumina-silica system is point 2 in Rankin and Wright's diagram, having a melting point of 1165 deg. C., as determined by viscosity measurements,[8] and corresponding to a composition 23.25 per cent CaO, 14.75 per cent Al_2O_3, and 62 per cent SiO_2. Therefore, as soon as a temperature of 1165 deg. C. is reached by the charge during its descent downward toward the hearth, a certain amount of this low-melting eutectic may be formed. However—and this is an important point—since this eutectic differs widely in its composition from that of the slag ingredients as a whole, and since it has with its high silica content an extremely high viscosity at all furnace temperatures, it is very probable that no formation of liquid slag sufficient to cause any appreciable downward movement of the slag occurs until a temperature is reached corresponding approximately to the melting point of the entire slag ingredients. At least, until there is available some experimental data on this subject, the above assumption is the simplest one that can be made.

Since with this asumption the melting point of a slag is equal to either point 5 or point 6 of Rankin and Wright's diagram, slag formation actually begins in the furnace at a temperature of either 1310 deg. C. or 1265 deg. C., these being the melting points respectively of these two ternary eutectics. The composition of point 5 is 38 per cent CaO, 20 per cent Al_2O_3, and 42 per cent SiO_2; and of point 6 is 47.2 per cent CaO, 11.8 per cent Al_2O_3, and 41 per cent SiO_2.

When, after melting, the slag has its temperature raised to such a point as to flow around and entrap within it the molten iron globules, its metallurgical function in the blast-furnace may be said to have become operative. It is very probable that this initiation of its function as a desulphurizer and source of silicon corresponds more or less closely to a definite value of viscosity, placed tentatively at 10. It is doubtless preferable to assume that, instead of the molten slag flowing around the molten iron globules at the time when the viscosity of the former reaches a value of 10, the molten iron globules fall by gravity from a higher level into the viscous slag at a somewhat lower zone in the shaft and are imbedded therein or trapped therein by the motion of the molten slag. At any rate, the initiation of the desulphurizing process begins when intimate contact is made between iron globules and molten slag, whether the slag entraps the globules *in situ* or after the latter have moved a certain distance down the shaft.

On the other hand, measurements made on slags at flush indicate that the slag as it flows from the cinder notch has on an average a viscosity of 4.

We are concerned then chiefly with the temperature relations of the slag as it decreases from a viscosity of 10 to a viscosity of 4. This temperature interval, during which the important chemical reactions of silica reduction and desulphurization occur, may be appropriately termed the "active range" of the slag.

For the purpose of conserving coke, it should be the aim of the superintendent to keep this active range of the slag as low on the temperature scale as possible. If we leave out of consideration the black "scouring" slags containing a large percentage of iron oxide usually accompanied by undue irregularities in charge descent, it does not seem probable that in a furnace producing basic iron the operator can choose a slag having too low an active range. High sulphur in pig-iron is usually caused not by the fact that this range is too low, but that the range is too narrow, affording no flexibility and allowing insufficient time for the iron globules to be in intimate contact with the slag.

As will be shown later it is possible, having given an ore or ore mixture to determine with the aid of slag viscosity tables that slag composition which will have the lowest practicable active range.

In using the tables, there are certain precautions which must be observed by the operator.

Since, for reasons advanced above, the minor constituents are not to be given consideration, it is necessary first to calculate all slag analyses to a basis of 100 per

[8] See *Technical Paper* 189, p. 26. The melting point as determined by Rankin and Wright, using the crystallographic method of quenched melts, is 1170 deg. C. ± 5 deg.

cent lime, alumina, and silica. In this way, all possible slag compositions can be expressed in terms of the three constituents of the ternary system CaO-Al_2O_3-SiO_2. The temperature-viscosity relations of all slags is simply a function of two independent variables, alumina and lime, or alumina and silica, or lime and silica. Obviously, the percentage of the third constituent is fixed as soon as the percentages of the first two constituents are known. This arithmetical calculation must be made whenever a slag is to be referred to the slag viscosity tables, so that it will be advisable to indicate the necessary procedure.

Let us consider a slag which shows the following analysis:

	Per Cent
CaO	40.17
Al_2O_3	13.07
SiO_2	35.32
MgO	5.51
CaS	3.87
Other oxides	2.06
	100.00

This particular slag represents average practice in the United States, according to analyses representing 44 per cent of the blast-furnace tonnage.

The calculation is as follows: The percentages of CaO, Al_2O_3, and SiO_2 are added together, making a total of 88.56 per cent. The percentages of these three constituents are then multiplied each in turn by the factor $\frac{100}{88.56}$. This gives as the composition of the slag: 45.36 per cent CaO, 14.76 Al_2O_3, and 39.88 SiO_2, a total of 100 per cent.

The operator who is in the habit of associating certain slag characteristics to a slag containing 12 per cent Al_2O_3 and 36 per cent SiO_2 by actual chemical analysis, must carefully avoid comparing such a slag with one of 12 per cent Al_2O_3 and 36 per cent SiO_2 as given in the tables without first recalculating the slag to a basis of 100 per cent lime, alumina, and silica. After this recalculation it is probable that this slag will be represented in the tables by a 13 per cent Al_2O_3, 39 per cent SiO_2 slag.

While it may seem that emphasis on such a simple matter is unnecessary, it is just such minor points as this which will make the application of the tables appear at all unusual to an operator schooled to think only in terms of percentages by analysis without regard to the relative proportions of CaO, Al_2O_3, and SiO_2. Fortunately, this is a difficulty which is not serious.

As was explained in some detail in Bureau of Mines *Technical Paper* 187, the matter of obtaining a representative sample of slag at flush for chemical analysis is a difficult problem. A single sample will in no case give the correct average slag composition, and in some cases not even approximately so. Three samples, taken at the beginning, middle and end of each flush and a sample of the slag at cast will, when made into a well-mixed composite sample, yield a fairly good representative sample. The writer has several times witnessed a spirited discussion between a blast-furnace superintendent and a works manager over a supposed change in slag composition, amounting to several per cent SiO_2, which discussion resulted in a change in the charge, when two samples taken during the same flush showed more than 2 per cent difference in their SiO_2 content. The best method of combating this operating difficulty is obviously to take as frequent slag samples as can be handled by the analytical staff at the works, and if the results obtained in this way justify a further increase in the number of samples, to increase the number of analysts.

Mention has also been made of the errors which are often found in works analyses of slags, due to the common practice of dissolving the sample in hydrochloric acid, instead of analyzing according to the accurate method of fusion with sodium carbonate. The error introduced by the former method is greater in the case of slags high in alumina than in low alumina slags, although even a moderate alumina content may cause serious difficulty. This source of inaccuracy should be given careful consideration by every blast-furnace chemist, and corrected where found to be prevalent. In most cases, lime, CaO, is not determined as such in the analysis of the slag, but is obtained "by difference," and includes other oxides such as Na_2O, K_2O, TiO_2, and sometimes MgO and MnO where these two oxides are not separately determined. In addition, this expedient, used for the sake of saving time, throws the sum of all the analytical errors into the CaO percentage where, more than anywhere else, an accurate value is required on account of the fact that the slag properties are peculiarly susceptible to small changes in the lime content.

The operator must therefore at the outset eliminate the above-mentioned difficulties of slag sampling and analysis, or at least reduce them to a minimum, before he is in a position to derive the greatest benefit from the application of the slag tables.

The Slag Viscosity Tables

In Bureau of Mines *Technical Paper* 187 are given the complete slag tables, showing the viscosity in C.G.S. units of iron blast-furnace slags for even percentages of alumina between 7 and 24 per cent; over a wide lime-silica range; for temperatures of 1350 deg. C. (2462 deg. F.), 1400 deg. C. (2552 deg. F.), 1450 deg. C. (2642 deg. F.), 1500 deg. C. (2732 deg. F.), 1550 deg. C. (2822 deg. F.), and 1600 deg. C. (2912 deg. F.); and also the temperatures at which the different slags have viscosities of 2, 4, 6, 8, 10, and 12 C.G.S. units.

The tables cover a definite portion of the ternary system CaO-Al_2O_3-SiO_2, being confined to the stability fields of calcium metasilicate and gehlenite (see *Technical Paper* 187). This particular portion of the ternary system was selected after examination of the relative proportions of lime, alumina, and silica in a number of slags representing widely different practices.

The range of slag composition included in the tables is as follows:

RANGE OF COMPOSITION INCLUDED IN SLAG VISCOSITY TABLES

(Calculated to Basis of 100 per cent CaO, Al_2O_3, SiO_2)

Al_2O_3 Per Cent	SiO_2 Per Cent	CaO Per Cent	Al_2O_3 Per Cent	SiO_2 Per Cent	CaO Per Cent
7	50–43	43–50	16	48–35	36–49
8	50–43	42–49	17	47–33	36–50
9	49–42	42–49	18	46–32	36–50
10	49–42	41–48	19	45–31	36–50
11	49–42	40–47	20	42–30	28–50
12	49–40	39–48	21	42–29	37–50
13	49–39	38–48	22	40–28	38–50
14	48–37	38–48	23	38–28	39–49
15	48–36	37–49	24	39–28	37–48

It is true that a small number of furnaces are run on a dolomitic or high magnesia flux, in which cases the percentage of MgO in the slag will be well above 8 per cent, which is the upper limit fixed for the direct application of the viscosity data given in the tables. The relative importance, however, of this practice has not

yet seemed sufficient to warrant a systematic investigation of the quaternary system CaO-MgO-Al_2O_3-SiO_2. This problem will doubtless be solved, nevertheless, in the not distant future. Since the practicability of smelting to advantage titaniferous iron ores unusually high in TiO_2 has been demonstrated by Auguste Rossi, it is probable that the quaternary system CaO-Al_2O_3-TiO_2-SiO_2 will also ultimately demand attention at the hands of investigators.

Slag Control

With a given supply of raw materials—ores, coke, and limestone—the attainable economy in coke consumption is, for a specified grade of iron, chiefly dependent upon the maintenance of a proper slag composition. In the discussion of furnace operation which follows it has been convenient for the sake of brevity to assume that the reader is familiar with the salient features of pig-iron manufacture as given in the various text-books. In even a cursory study of this important industrial process it becomes evident to most readers interested in the subject that the question of the choice of slag composition has hitherto been entirely arbitrary on the part of the superintendent. In his decision he has been guided by previous furnace records and by his own experience. Nevertheless, he is called upon almost daily to meet unusual operating problems where his course of action is the combined result of intuition and shrewd conjecture. In the majority of cases such action involves a change in slag composition due to altering the composition of the charge, increasing or decreasing the burden, or both. The blast-furnace superintendent's task is at best a difficult one, and it becomes increasingly complex when furnace operations are interrupted or made irregular by such contingencies as a shortage of coke or other raw materials.

It is common in text-books to see a chapter on slags open with such a statement as, "It is required to make a slag of the following composition: 50 per cent CaO, 15 per cent Al_2O_3, and 35 per cent SiO_2." There are certain inherent objections to such a statement. The most cogent is that the purpose of a blast-furnace is not to produce a slag of a definite composition, but on the contrary to produce iron of a definite grade, and what is more to the point, from a limited selection of ores. Probably no possible combination of his ores would enable an operator to attain a slag of such a composition as that "required" above. His problem is to utilize the ores on hand to the best advantage regardless of his personal or acquired slag preferences and with a minimum coke consumption.

Illustrative Examples Taken from Practice

It is the chief purpose of this paper to point out (1) how an operator can determine what change in his charge should be made when an undesirable slag is being produced, and (2) how he can decide with the help of the slag tables, what is the "desired" slag corresponding to any given ore or ore mix, limestone, and coke. Both of these conditions can be arrived at by a purely mechanical procedure in which the personal equation of the operator is reduced to a minimum importance. A few examples taken from practice may illustrate the use of the slag tables.

The slag is making off-grade iron, high in sulphur, is chilling the furnace, i.e., running with difficulty from the cinder notch. The slag shows by analysis the following composition:

	Per Cent
CaO	42.51
Al_2O_3	13.28
SiO_2	32.77
CaS	4.02
MgO	5.50
MnO	1.20

Re-calculating to a basis of 100 per cent lime, alumina, and silica we find the relative proportions of these oxides are:

	Per Cent
CaO	48.00
Al_2O_3	15.00
SiO_2	37.00
Total	100.00

Referring to the slag tables, we see that the temperature-viscosity relations of this slag and those of the compositions immediately around it clearly indicate the presence of too much CaO. These values, taken from the tables, are given below in Table I.

TABLE I.

Al_2O_3 = 15 Per Cent		Active Range Temperature at Which		Width of Active Range
Per Cent		Viscosity = 4	Viscosity = 10	
SiO_2	CaO	Deg. C.	Deg. C.	Deg. C.
40	45	1,453	1,346	107
39	46	1,470	1,366	104
38	47	1,525	1,394	131
37	48	1,594	1,448	146
36	49	> 1,640[a]	1,568	...

[a] The symbol > signifies "greater than."

An examination of Table I shows that, while the width of the active range is sufficient, the slag demands an abnormally high furnace temperature in order to flow easily from the cinder notch, i.e., 1594 deg. C., and also that a slight increase in lime, due to many of the unavoidable irregularities in the charge would give a slag ($CaO = 49$, $SiO_2 = 36$) which is much too refractory, for satisfactory operation.

It is a well-known fact that extremely high-sulphur irons are most often met with in basic practice where a high percentage of lime is present in the charge. When any unavoidable fall in blast temperature occurs or when the descent of the charge is irregular or delayed, portions of the descending limey slag pass over quickly to the solid state, capable of acting chemically upon the pig iron very slowly if at all, in so far as desulphurization is concerned. In other words, the melting point of the slag lies dangerously near the temperature of the smelting zone. To maintain a furnace temperature sufficiently high to avoid this difficulty would call for an unreasonably high coke consumption and a short life of furnace lining. There appears to be considerable evidence that in basic practice many furnacemen entail an unnecessarily high coke consumption simply because they make use of a very limey slag where a less limey slag would produce an iron as low in sulphur and with the proper silicon content at a lower furnace temperature.

In the case above, the lime content of the slag (referred to 100 per cent lime + alumina + silica) could advantageously be lowered from 48 to 45 per cent. If any further difficulty was experienced due to a too hot or a too cold furnace, it could be ascribed logically to excessive or insufficient coke, and the necessary change made in the burden.

This illustrates in a general way how the tables may be used in helping to solve a slag problem which, unless successfully solved, might mean a shut-down.

It would be both interesting and profitable for the superintendent who has access to past furnace records

of pig and slag analysis and coke consumption to compare the conclusions drawn from data given in Table I for a number of slags with the actual results obtained. Unfortunately, in a large percentage of cases this is not feasible since the analysis of the slag does not include a determination of CaO as such, but only "lime" by difference.

Turning now from the case of the operator who is confronting the problem of avoiding a shut-down or continued off-grade iron due to improper slag composition, let us give our attention to the question of the initial decision as to the proper charge composition. This can be reached very conveniently by means of the slag tables, without making use of any rules-of-thumb or other maxims the applicability of which may be doubtful.

We will examine the most desirable slag practice using a mixture of equal parts of soft and semi-hard Tennessee ores, having the following composition:

	Per Cent
Fe	42.8
SiO_2	24.3
Al_2O_3	3.8
CaO	2.1

The coke contains 5 per cent SiO_2 and 3 per cent Al_2O_3. Let us assume a basic iron product containing 1 per cent Si and 94 per cent Fe.

Each pound of ore yields $\frac{0.428}{0.94}$ or 0.455 pounds of pig iron. For 1 pound of pig iron produced it is necessary to flux 1 x $\frac{0.243}{0.455}$ or 0.534 pound of SiO_2 and 1 x $\frac{0.038}{0.455}$ or 0.083 pound of Al_2O_3. To these amounts, assuming a fuel consumption of 2240 pounds of coke per ton of pig iron, must be added, respectively, 0.05 pound SiO_2 and 0.03 pound Al_2O_3, making a total of 0.584 pound SiO_2 and 0.113 pound Al_2O_3 per pound of pig iron. Since the pig iron contains 1 per cent Si, equivalent to 0.021 pound SiO_2 per pound of pig iron, this amount must be deducted from the available SiO_2, leaving a balance of 0.563 pound SiO_2 per pound of pig iron.

Assuming that we charge pure limestone (100 per cent $CaCO_3$) or a stone which contains no alumina or silica, and that the burden ratio was not changed, the ratio of silica to alumina in the slag would be equal to $\frac{0.563}{0.113}$ or 4.98, regardless of how much limestone is charged. Taking this ratio for the present as constant and equal to 4.98, it is possible to calculate directly the possible slag compositions corresponding to varying amounts of limestone charged.

Let x = per cent of CaO
y = per cent of SiO_2
z = per cent of Al_2O_3

Then $y/z = 4.98$ (1)

$x + y + z = 100$ (2)

Assuming that the proper slag will contain between 38 and 50 per cent CaO, we first substitute the value 38 for x in equation (2).

Then $y + z = 100 - 38 = 62$ (3)

From (1) $y = 4.98\ z$ (4)

Substituting (4) in (3), we have

$5.98\ z = 62$

or $z = 10.3$ per cent Al_2O_3.

Hence,

$y = 100 - (38 + 10.3) = 51.7$ per cent SiO_2.

Repeating this calculation for the remaining percentages of CaO between 38 and 50 per cent, we obtain the set of composition shown in Table II. There is also given opposite these compositions the temperatures at which these slags attain a viscosity of 4 and 10, indicating the position of the active range, obtained by referring to the slag tables.

TABLE II.

Percentage Composition			Active Range		Width of
			Viscosity = 4	Viscosity = 10	Active Range
CaO	Al_2O_3	SiO_2	Deg. C.	Deg. C.	Deg. C.
38	10.3	51.7	.....	.....	.....
39	10.2	50.8	.....	.....	.....
40	10.0	50.0	.....	.....	.....
41	9.8	49.2	1,588	1,414	174
42	9.7	48.3	1,544	1,396	148
43	9.5	47.5	1,509	1,382	127
44	9.3	46.7	1,490	1,369	121
45	9.2	45.8	1,471	1,357	114
46	9.0	45.0	1,452	1,345	107
47	8.8	44.2	1,443	1,320	123
48	8.7	43.3	1,423	(a)	113
49	8.5	42.5	1,392	(a)	82
50	8.3	41.7	.....	.....	.....

(a) Solidifies at 1310 deg. C.

As is obvious the calculation of the compositions given in Table II can be performed graphically with great ease after the composition of the first and last members of the series is known, since the various percentages are all linear functions of one another.

An examination of the temperature-viscosity relations of the possible slag compositions as shown in Table I does not disclose any pronounced minimum active range, nor is the active range raised by increasing lime, at least up to 49 per cent CaO, but on the other hand it is lowered thereby.

Regarding the possible temperature-viscosity relations of those compositions not in the tables, it can safely be said that a slag containing a higher percentage of lime than is given in the tables is unsuitable for proper and economical furnace operation. Such a slag lies in the stability field of calcium orthosilicate, and has a melting point which increases with astonishing rapidity with increasing lime. Probably "liming up" of a furnace is usually due to the presence of such a slag whose composition lies in the orthosilicate stability field (see Fig. 1, Bureau of Mines *Technical Paper* 189). It may be concluded then that although the active range of the slags shown in Table II is lowered by increasing lime up to 49 per cent CaO, any further increase in lime will produce a slag of unusually high melting point and therefore undesirable. From the table it is also seen that for 49 per cent CaO the width of the active range has been considerably reduced, and that for both 48 and 49 per cent CaO the slag is characterized by that peculiar property, found only in low alumina slags, of solidifying sharply from a fairly fluid melt.[1] It is, of course, desirable to get away from such a condition, so that the operator in choosing his slag will select a somewhat less "limey" slag, say with 44 per cent CaO, 9.3 per cent Al_2O_3, and 46.7 per cent SiO_2 having a viscosity of 4 at 1490 deg. C. and a viscosity of 10 at 1369 deg. C.

Suppose the limestone showed from analysis the following: 48.50 per cent CaO, 3.25 per cent SiO_2, and 1.20 per cent Al_2O_3.

It has been shown above that the amount of available SiO_2 in ore and coke which must be fluxed is equal to 0.563 pound per pound of pig iron, and of Al_2O_3 is

[1] See Bureau of Mines *Technical Paper* 189, pp. 27-28.

0.113 pound. Since we have decided to use a slag having 44 per cent of CaO (on a basis of 100 per cent lime, alumina, and silica), it is obvious that the weight of CaO which must be charged per pound of pig iron is equal to $(0.563 + 0.113) \times \frac{44}{56}$ or 0.53 pound. But the CaO present in the ore, amounting to 2.1 per cent will yield $\frac{0.021}{0.455}$ or 0.04 pound of CaO per pound of pig iron.

The amount of CaO to be charged as limestone is then equal to $0.53 + 0.035 - 0.04 = 0.525$ pound per pound of pig iron, which amounts to $\frac{0.525}{0.485}$ or 1.08 pound of limestone per pound of pig. In the preceding calculation, the value 0.035 represents the number of pounds of lime per pound of pig which must be charged to combine with the sulphur of the charge to form calcium sulphide, CaS. This is based on an assumed percentage of 3.8 CaS in the slag.

It is of interest now to calculate what effect the failure to consider the silica and alumina in the limestone had in so far as their effect on the silica-alumina ratio was concerned. The amount of silica in the limestone per pound of pig is 0.53×0.0325 or 0.017 pound, increasing the available SiO_2 from 0.563 to 0.580; while the amount of alumina is 0.53×0.012 or 0.006 pound, increasing the alumina from 0.113 to 0.119. The revised silica-alumina ratio is then $\frac{0.580}{0.119}$ or 4.87, instead of 4.98. This difference may, in this case, be neglected for practical purposes in deciding upon the proper slag composition. Its effect on the lime charged, however, has been taken into account.

It may possibly be advisable when using a limestone unusually high in alumina or silica first to revise the silica-alumina ratio. This can be done in all cases with a high degree of accuracy by first assuming the slag to contain 45 per cent CaO, and then making the correction as shown above from a knowledge of the stone analysis. After this is done the procedure used in arriving at the data given in Table II is the same as was used.

We will consider in conclusion the case of a Lake ore of the following composition:

	Per Cent
Fe	55.4
SiO_2	6.8
Al_2O_3	1.6
CaO	0.3

Using the same coke analysis previously given and assuming a fuel consumption of 1800 pounds of coke per ton of pig, calculations made in a manner similar to those in the case of the Tennessee ore mixture will, for a basic iron containing 1 per cent Si and 94 per cent Fe, furnish the data given in Tables III and IV. Here, however, the calculations have been extended to include the revised silica-alumina ratio mentioned above, for a limestone of the composition already stated.

TABLE III.

Lb. pig iron per lb. ore	0.589
Lb. SiO_2 from ore per lb. pig	0.115
Lb. Al_2O_3 from ore per lb. pig	0.027
Lb. SiO_2 from coke per lb. pig	0.040
Lb. Al_2O from coke per lb. pig	0.024
Lb. SiO_2 reduced to Si	0.021
Lb. SiO_2 from stone (assuming 45% CaO in slag)	0.013
Lb. Al_2O_3 from stone	0.004
Lb. SiO_2 available for slag	0.147
Lb. Al_2O_3 available for slag	0.055
Revised silica-alumina ratio	2.7

TABLE IV.

Percentage Composition			Active Range		Width of
CaO	Al_2O_3	SiO_2	Viscosity = 4 Deg. C.	Viscosity = 10 Deg. C.	Active Range, Deg.
37	17.0	46.0	1,548	1,410	138
38	16.7	45.3	1,527	1,411	116
39	16.5	44.5	1,527	1,408	119
40	16.2	43.8	1,527	1,405	122
41	15.9	43.1	1,516	1,395	121
42	15.7	42.3	1,508	1,390	118
43	15.4	41.6	1,498	1,383	115
44	15.1	40.9	1,474	1,361	113
45	14.9	40.1	1,453	1,346	107
46	14.6	39.4	1,458	1,364	94
47	14.3	38.7	1,506	1,388	118
48	14.0	38.0	1,618	1,432	186

In Table IV a well-defined minimum active range is noted at 45 per cent CaO. For basic iron, therefore, this slag composition is indicated, although for foundry iron a higher furnace temperature, corresponding to 42 or 43 per cent CaO, might be advantageously used. Adhering, however, to the question of basic iron, it is readily calculated that the weight of CaO needed per pound of pig iron is equal to $0.202 \times \frac{45}{55}$ or 0.165 pound. The lime present in the ore, amounting to 0.3 per cent, will yield $\frac{0.003}{0.589}$ or 0.005 pound CaO per pound of pig iron. Assuming, as before, that 3.8 per cent CaS is present in the slag, it is readily calculated that the amount of limestone which should be charged is equal to

$$\frac{0.165 + 0.012 - 0.005}{0.485}$$

or 0.355 pound per pound of pig.

Conclusions

It seems reasonable to conclude that the slag-viscosity tables are destined ultimately to become as useful to the metallurgist and blast-furnace operator as the steam tables are at present to the mechanical engineer, although this does not preclude the possibility of their being revised and expanded from time to time.

It remains for each individual furnaceman to make the greatest possible use of the information contained in the viscosity tables.

It is not unreasonable to conclude that viscosity measurements similar to those already made on iron blast-furnace slags will be performed in the case of both copper and lead slags with the same relative measure of successful industrial application.

The dependence of fuel economy on the maintenance of the proper slag composition has not been elaborated in the present paper. It is a fact so well-known to metallurgists that it hardly requires any explanation. With this in mind, it becomes clear that, aside from any question of increased pig-iron production, an intelligent slag control in the blast-furnace is a most important step toward enormous savings in our available coal supply.

Cleveland, O.

Statistics on the German production of potash for 1917 are given in a dispatch from Vice-Consul J. C. McNally, at Zurich, Switzerland, as follows:

	Per Cent K_2O	Tons	K_2O Tons
Carnallite	9–10	4,290	400
Raw salts	12–15	393,360	52,200
Fertilizing salts	20–22	201,190	42,250
Fertilizing salts	30–32	23,870	7,400
Fertilizing salts	40–42	321,760	131,900
Potassium chloride	63	166,370	105,000
Potassium sulphate	42	31,350	13,170
$K_2Mg(SO_4)_2$	.....	1,452	150
			352,470

Electric Welds

Notes on Welding Machinery, the Properties and Microscopy of the Welds and a Peculiar Occurrence of Widmanstattian Structure

By ERNEST EDGAR THUM

WITH the advent of high-power electric welding machines both for spot and butt welding, an increasingly large number of joints are being made in this manner. Special machines have been developed for butt-welding of various shapes ranging from the smallest wire to heavy tires; for the manufacture of teapot spouts, all sorts of enameled ware, tubes and pipe. Spot welding machines of various sizes are also in operation, which instead of welding a continuous seam will fasten two or more plates together at isolated spots, making a joint much after the style of a riveted connection.

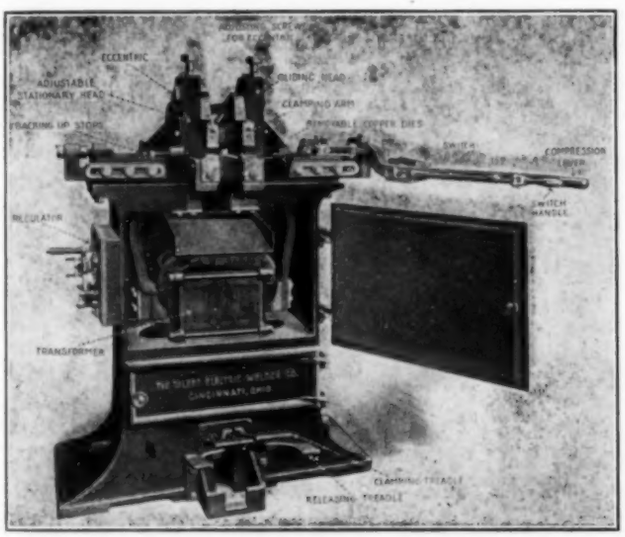


FIG. 1.—ELECTRIC BUTT WELDER

Electric Welding Machines

The usual butt welder (Fig. 1) consists of a suitable pair of heavy copper clamps or vises for holding the work. One of these clamps is attached to a fixed and one to a sliding head, the latter of which can be moved toward the other with considerable force during the welding operation by manual operation of a compression lever. The work to be welded serves as part of the secondary circuit of an alternating current transformer, built into the base of the machine. This secondary usually has but one turn, a heavy water cooled copper bar bent up and ending in the vises mentioned above. The primary winding will contain fifty or more turns, depending upon the voltage of the power line and the voltage required to overcome the resistance of the pieces to be welded.

The operation of the machine, therefore, involves drawing a few kilowatts of electric power from a suitable supply, transforming it into a current ranging in voltage from about two to ten volts and perhaps as many thousand amperes, and then passing this heavy amperage through the pieces to be welded while they are pressed tightly together with the joint about midway between the gripping vises. In comparison with the rest of the secondary winding, these pieces of material to be welded have a small cross section and high specific resistivity; the passage of the current is consequently attended by the development of a large amount of heat at the joint, where the pieces rapidly attain a very high temperature. The constant pressure applied through the clamping arms forces the two together as the softening or welding temperature is attained, upsetting a considerable amount of plastic metal as in Fig. 2, or, if the pressure and current are held a longer time, extruding considerable burned metal in the form of a perpendicular fin (Fig. 3). The current is now shut off, the piece cooled and annealed (if the latter operation is thought necessary), and the weld is completed by grinding off the fin.

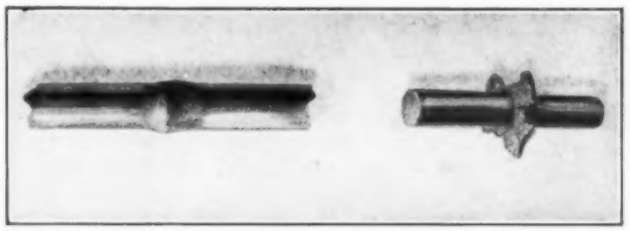


FIG. 2.—UPSET WELD FIG. 3.—FLASH WELD

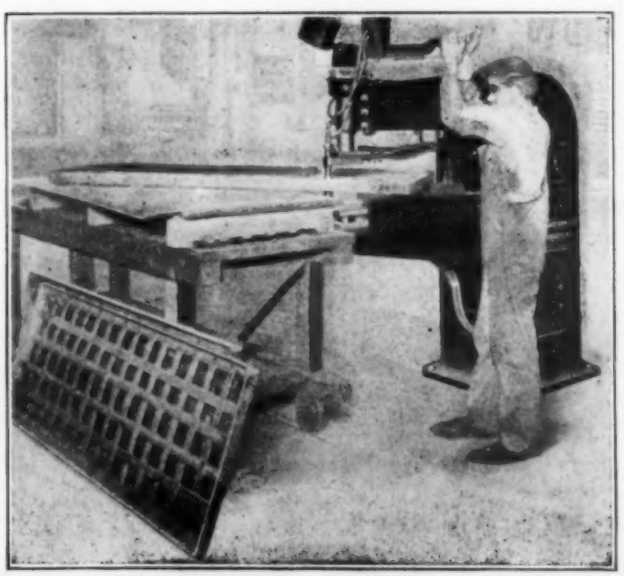


FIG. 4.—SPOT WELDER BUILDING LATTICED FRAMES

Spot Welding

The operation of the spot welder is in no wise different. As shown in Fig. 4, the gripping vises are replaced by heavy copper dies or electrodes which close upon the sheets to be welded. The current is switched on and heats intensely the metal throughout a small region between the copper terminals, and the sheets are welded over a roughly circular spot. Extrusion of metal in this case is prevented by the continuous lateral support which the cold sheet affords the heated area; however, a small crater-like depression is formed by the pressure of the die upon the plastic metal (Fig. 5).

A welding operation may be regarded merely as a process of bringing the particles of two separate pieces of material within the region of their mutual molecular attraction either by means of heat (increasing their plasticity) or by pressure (increasing their proximity) or by both heat and pressure. If time and sufficiently close contact is afforded, the molecules of the one piece migrate into the other even in the cold and form an alloy at that point. It follows that the making of an electric weld is an exactly similar operation to that of welding on an anvil. The great advantage lies in the efficient method of producing the heat electrically, and the pressure mechanically. This results in an enormously increased speed of operation, and indirectly it eliminates the formation of undesirable metallic oxides on the heated surface which are so troublesome to the blacksmith. This is due to the fact that the heating is done so much more rapidly than in the forge, out of contact with the heated air blown through a bed of

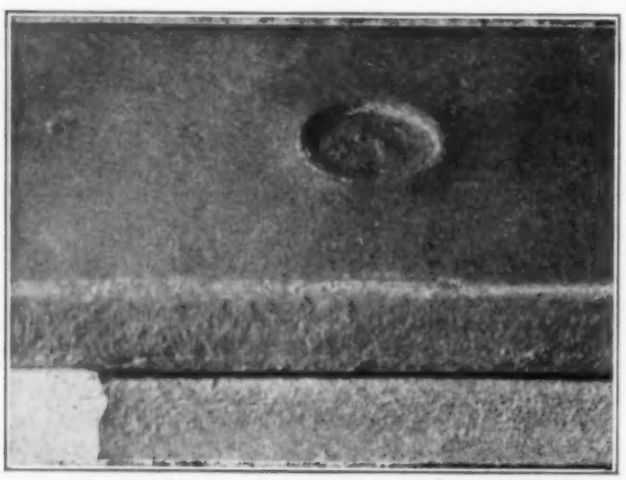


FIG. 5.—SPOT WELD JOINING TWO STEEL SHEETS

coals, and withal so quickly and efficiently that only a small amount of oxide is formed, and this is immediately eliminated in the fin of hot metal squeezed out from the welded zone.

Welding High Speed Tools

Shortly after the outbreak of the war, speculation in metals forced the price of high speed or tungsten steels for machine tools to such an exorbitant figure that an ordinary lathe tool became a piece of precious metal, difficult to procure at any price. Many plants resorted to the expedient of spot welding a small inset of high speed steel into a notch cut in the end of a carbon steel tool (Fig. 6). This was a very economical procedure, inasmuch as the welding operation is quite inexpensive, and the stub end of an old lathe tool of high speed steel too short for the holder could be cut up and used to make the working edge of several standard size tools.

Considerable trouble was experienced, however, from the tendency of the high speed inset to break off, cracking through at a short distance above the welds.[1]

FIG. 6.—LATHE TOOL WITH CUTTING POINT OF HIGH SPEED STEEL

A microphotograph of the weld showed very little interpenetration of the two metals, the alloy which was formed at the junction by the welding current being about 0.0006 inch in thickness.

The troubles following welding of high speed steel resembled the familiar "season cracking" of bronzes. These latter cracks probably result from failure along surfaces which are under initial stresses (set up, in the case of brass and bronze, by cold working). The strains resulting from these stresses are usually beyond the power of direct observation under the microscope, and no evidences of structural weakness could be observed in the steel inset, even though studies of low carbon welds showed considerable evidence of slip bands, as will be seen in what follows.

It was found, however, that cracking in service could easily be eliminated by placing the tool in a hot oven immediately after welding, before the piece had a chance to cool, and annealing to a dead soft state by cooling in lime, later hardening and tempering the tool in the proper manner. The time at the annealing temperature was apparently sufficient to allow the molecules which were strained in some manner during welding to adjust themselves to the orientation required for stability at low temperatures.

Welding High Carbon Steels

In order to throw some light upon the chemical and physical changes induced by the welding process, pieces of 0.97 per cent carbon drill steel, of ⅝-inch diameter, were studied after butt welding. Test pieces of the original stock and of both annealed and unannealed welds were made by mounting in a lathe, removing the excess metal of the fin, and then turning or grinding a short length of the bar accurately to a diameter of one-half inch, with the weld in the center of the turned portion. In the unannealed welds, the turned portion was but one-half inch in length in order that the failure would be forced to occur within the portion of the bar altered in constitution by the welding heat. Tension tests of the unannealed welds showed, in all cases, a

[1]The writer investigated this and other phenomena attending electric welding for the Thomson Electric Welder Company of Cincinnati during 1916, and through their courtesy is enabled to present the more interesting results of his examinations.

failure with little or no necking occurring at the end of the turned portion—that is to say, farthest from the weld and in the softest portion of the test piece. The strength thus developed was much higher than even the strength of the original steel, and it is clearly evident that all parts of this weld have a higher ultimate strength than the original bar. The average results of the tension tests follow:

Material	Ultimate Strength Lb. per Sq.In.	Contraction in Area, Per Cent	Elongation in 1 In., Per Cent
Original tool steel	114,100	12	10
Unannealed weld	158,700	2	3
Weld annealed at 750° C.	100,800	24	16

Annealed Welds

In the annealed bars failure always occurred at the weld, accompanied by considerable necking, strictly limited to the close proximity of the point of failure. The marked increase in ductility of the steel at the weld suggested the possibility of a very considerable change in carbon content at that point. Metallographic examination substantiated this suspicion—eye examination of a polished surface showed a zone some one-eight of an inch long which etched much lighter than the boundaries, and under the microscope exhibited primary ferrite in pearlite. Fig. 7 shows a micrograph of the edge of this decarbonized zone, indicating an unmistakable variation in carbon content from the eutectoid stock at the left toward the decarbonized weld. Conviction became certainty upon analyzing saw dust from cuts through the weld and through the stock; the former gave 0.57 per cent and 0.51 per cent for two different welds, while the original stock returned 0.97 per cent carbon.

An explanation of this variation of the carbon content is not apparent. The welding current is on but a few seconds; for the matter of a second or thereabouts the temperature is so high that considerable iron is burned in the plastic material squeezed out by the pressure, but then the current is immediately interrupted and the piece rapidly cools. Undoubtedly a small amount of iron oxidizes at the surface to be welded, but this is entirely extruded, no oxides of iron nor blowholes of carbon monoxide being observed in any section. Again, the axis of the bar—which while the hottest, is also the furthest from the atmosphere—evidences the maximum amount of decarburization. How a weld can be made without blowholes, or how a piece of steel can be decarbonized without the deleterious effects attending so-called "burning" are points yet to be investigated.

Some microscopic examinations gave hints of a carbon migration away from the welded spot back into the unaffected stock. However, the problem of demonstrating a high carbon zone between the weld and the stock was attacked by a senior student at the University of Cincinnati with negative results. One hardly conceives the existence of a driving force during this operation capable of transporting carbon any great distance in the few seconds a butt weld is at a reasonably high temperature, and yet the speed of penetration of oxygen into the steel and carbon monoxide outwardly appears incredibly rapid. Numerous gas cavities, on the other hand, form readily when spot welding rusty structural steel.

Unannealed Welds

The unannealed weld in eutectoid steel furnishes a perfect specimen for metallographists. The thermal gradient of the heated pieces rises sharply from slightly above room temperature at the vise to a maximum at the joint. In like manner, the axis of the rod is materially hotter than the surface. Just before the current is switched off, an ellipsoidal-shaped core of well defined boundaries has been heated to and beyond the critical temperature with the result that within this zone the steel is then austenitic, that is to say, the iron carbide is absorbed in solid solution; while just without these boundaries the steel has been annealed to the sorbitic state (or remains in the pearlitic condition, if that were the structure of the original bar). Fig. 8 shows the transition of a slowly cooled hypo-eutectoid steel at the left into the cloudy sorbite at the right, beautifully illustrating in one view the entire mechanism of cementite absorption.

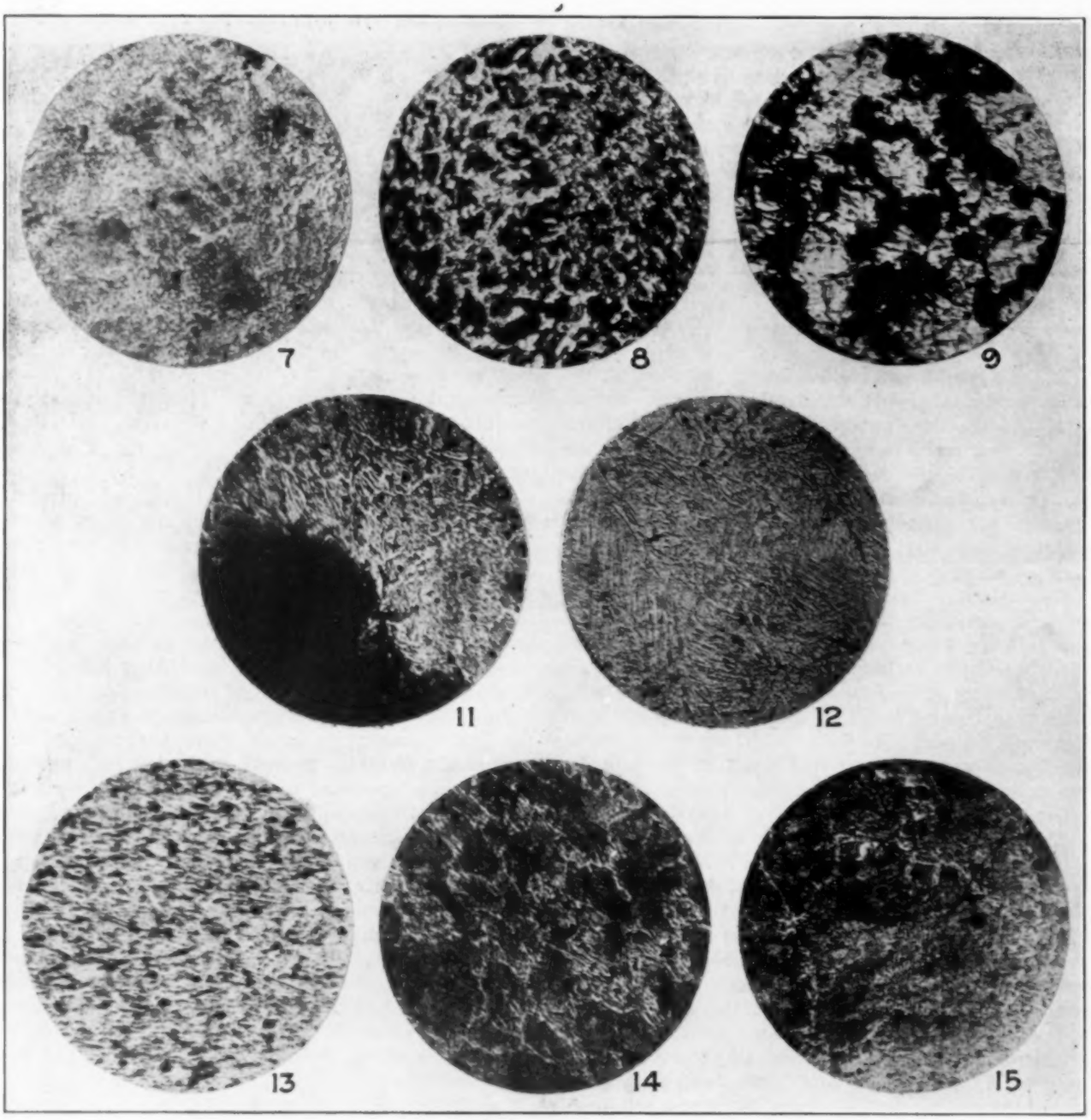
Immediately upon interrupting the electric current, the austenitic core is "quenched," in that its surrounding cold and unaltered sheath abstracts heat very rapidly by conduction, with the result that the core exhibits every possible decomposition product between austenite and pearlite, regularly arranged in bands. The lines of demarcation are sometimes so clear that the naked eye can observe a dark band developed by the quick etching so characteristic of troostite. An instance of this is given in the micograph shown in Fig. 9, where the lighter martensite on the right changes into the dark-etching spots of troostite on the left in a narrow zone bounded approximately by the width of the field.

Within the space of about twice the diameter of the piece, a weld before annealing possesses a core whose center exhibits nearly the maximum hardness attainable after quenching such a steel. Entirely surrounding this core are layers or muffs of similar form and definite boundaries which gradually change in hardness and toughness to that of the original stock—in case the latter was in a soft condition before welding. In welding hardened steels, on the other hand, the outer muff surrounding the core, being in the sorbitic condition, is liable to be softer than the stock. Barring the decarbonized zone, this entire alteration can be obliterated by proper annealing, after which the entire tool or any part of it can be given any requisite hardening or tempering.

The statement can be drawn from the above remarks that a welded bar, not heat treated, will break at some distance from the joint under static load, but at the weld if tested under sharp, eccentric impact. After heat treatment, the exact opposite will occur, as the joint will then be the weakest and most ductile part of the bar, due to a local decarbonization.

Welding Structural Steel

In order to show a comparison, in a qualitative way, of the strength of a rivet as compared with that of a spot weld, four 3 x 8-inch bars were cut from ⅜-inch stock structural steel plate. Two of these were riveted together with two ¾-inch rivets, one driven 1¼ inches from either end; while the other pair were spot welded at corresponding points with a machine designed to give a weld ¾-inches in diameter. The bars were then



FIGS. 7-9, 11-15

Fig. 7—Edge of decarbonized zone in annealing weld; x 220. Fig. 8—Absorption of ferrite into austenite in an unannealed welded low carbon; x 120. Fig. 9—Abrupt transition of martensite into troostite in butt welded eutectoid steel; x 220. Fig. 11—Blowhole in weld in structural steel; x 260. Fig. 12—Eutectiform structure developed in structural steel; x 260. Fig. 13—Structural steel, unaffected by welding; x 260. Fig. 14—Center of weld in structural steel; x 260. Fig. 15—Transition from sorbitic to eutectiform areas in structural steel; x 260.

laid flat on end supports, bent through about 45 degrees by a concentrated central load, and sawed lengthwise throughout, cutting through the center of the connection. A sketch of the bars, Fig. 10, will best show the results—the bars riveted together slipped past one another shearing the rivet, while the bars welded together showed absolutely no movement at the ends, nor did a microscopic examination of the weld show any indication of plastic yielding.

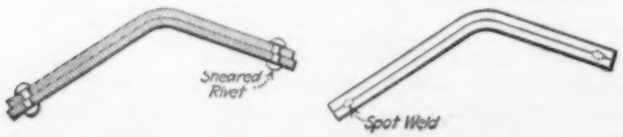


FIG. 10—COMPARISON OF STRENGTH OF WELDED AND RIVETED JOINTS

The stress acting on the neutral surface of a beam is one of horizontal shear, tending to move the upper and lower sections in opposite directions. The rivets in the above case were working under ideal conditions, and showed a perfect shearing failure.

The spot welds were working under exactly the same loading. However, in their case, the soft, low carbon rivet steel, working at a disadvantage in being under a considerable initial stress, is replaced by the hardened higher carbon structural steel, an integral part of the metal both above and below. In riveting, good metal is removed to make way for softer, while in welding,

a joint of harder and stronger metal is built up which is continuous with both the pieces connected.

A number of small pits were noticeable after sawing through the weld, an enlarged view of one of which is shown in the accompanying micograph, Fig. 11. The rounded black area at the left is the blow-hole, surrounded by a zone of light-colored ferrite, which in turn is backed by the hardened steel of unchanged carbon content, just indicated in the dark spot at the upper edge. This appearance is readily explained as follows: The sheets were taken from a stock pile and no attempt made to clean them of rust or scale before welding. At the time of welding, little chance was given for any extrusion of hot metal, owing to the continuous lateral support of the heated area; in this manner any impurity which orginally existed on the surfaces of the plates would be trapped and retained. The temperature of the weld is sufficient to effect a double decomposition of the oxide of the scale and carbide of the pearlite, thus:

$$Fe_3O_4 + 4Fe_3C = 15Fe + 4CO$$

The gas remains as a bubble in the center of a plastic mass of decarbonized iron.

Eutectiform Structure in Spot Welds

A very peculiar structure appears to a greater or less extent in all the spot welded low-carbon steel plates, but was not observed in any of the butt welds examined. It was found best developed near the outer edge of the spot welded structural plates of Fig. 10 and is shown in Fig. 12, at 260 diameters. The parallel striations, somewhat wavy, suggest pearlite, which it evidently cannot be, since the original metal is ordinary structural steel, whose microsection gives the typical hypo-eutectoid appearance (Fig. 13). A spheroidal mass at the center of the welds shows the microstructure of Fig. 14, a darkened background with the excess ferrite just being precipitated toward the edges of the crystalline grains. This entire central area, which etches dark in general, and which has been hottest during welding, is bordered by the peculiar light-etching eutectiform structure of Fig. 12, and which has not been so hot. The transition is extremely narrow, as is shown in Fig. 15 of the structural steel, and less clearly in Fig. 16 of a higher carbon spot weld. In turn, the eutectiform area grades into the unaffected original stock less abruptly.

This structure resembles martensite very much and one is tempted to class it as such, especially since unannealed welds are quite hard, and since this eutectiform structure is found adjoining sorbite. It is possible that the rapid conduction of heat by the relatively large and cold areas surrounding a spot weld, chilled and hardened the localized heated area of the weld and at the same time produced an inter-strain in the weld region which assisted in the formation of the martensite. While it is true that the exact center of a butt-welded joint is often troostitic and surrounded by a shell of martensite, this martensite in turn grades into the original stock through the well-known decomposition series without the development of this peculiar structure, which apparently requires a higher specific pressure for its production. In all the spot welds where this structure was observed the carbon content was moderate; low-carbon steels would not be expected to develop such large quantities of martensite nor would martensite be expected separating zones of sorbite and pearlite.

The markings within the borders of more than one crystalline area of Fig. 12 are notably straight and parallel, suggestive that the mass is one of very closely twinned metal, appearing like the structure shown in Fig. 17, which shows twinning striations in rock minerals. While so-called "annealing" twins are formed in steel by heating it above the transformation range after slight deformation, these crystalline entities so common in brass, for instance, show relatively broad parallel-sided strips crossing the crystal from boundary to boundary (Fig. 18).[2] Doubtless the local conditions of heat and pressure during the welding process might readily be such as to cause annealing twinning, but such are very rarely observed in alpha iron.

Narrow twins, such as these under investigation might prove to be, are known as Neumann bands (Fig. 19), but these are commonly thought of as being "mechanical" twins, that is, produced by shock in rigid metal rather than by squeezing the hot plastic metal between the dies of a spot welder. Neumanns are readily disclosed after etching, as are these markings, but the former are destroyed by heat above Ac_2, which temperature may easily have been exceeded in the weld, since the latter areas border a sorbitic structure.

X-Bands and Slip Bands

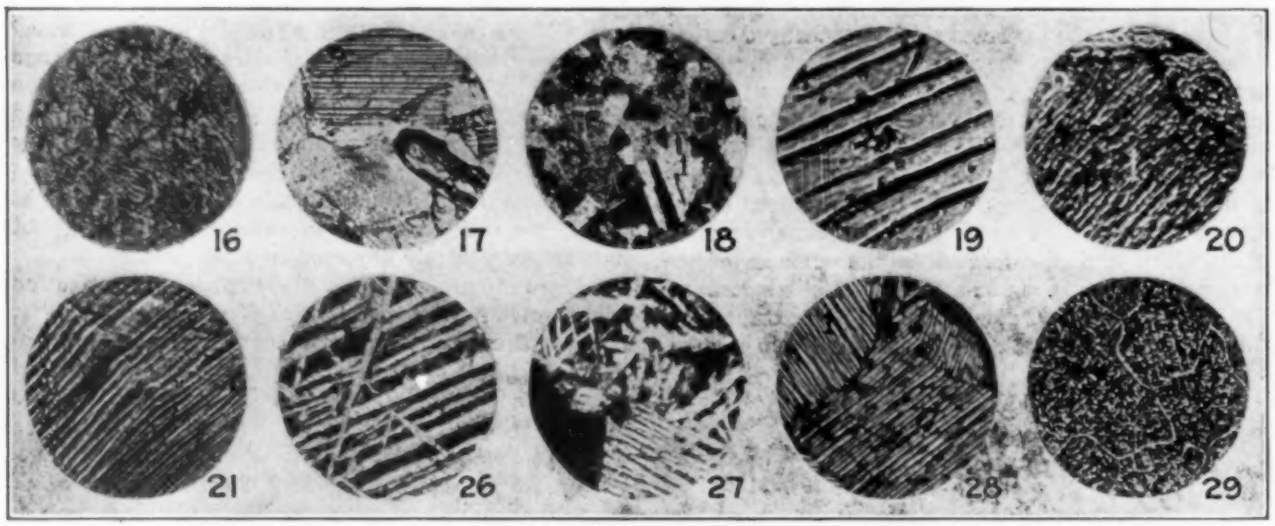
Certain aspects of Howe's X-bands (Fig. 20) show a noticeable resemblance to these markings under investigation. The X-bands occur on polishing and etching iron after a severe deformation. However, all the illustrations given in "The Metallography of Steel and Cast Iron" are of X-bands in ferrite, even though one infers from the text that they were also observed in 14-point steel. They appear before any heating has been applied—indeed, rest and temperature both obliterate them. It is probable that if any X-bands were formed early in the welding operation they would be healed during the heating near Ac and would not appear in a polished section taken some months later. Likewise, slip bands (Fig. 21) are ordinarily observed on deforming a polished surface, and the amorphous or twinned layers between the moving laminæ are not sufficiently wide to reappear after repolishing and reetching. Thus, while doubtless the strain under spot welding is sufficient to develop slip bands profusely, they could be expected to leave no trace after polishing and etching a specimen.

In the above discussion which successively eliminated the possibility that this peculiar eutectiform structure represents either annealing twins, mechanical twins, X-bands, or slip bands, it has been tacitly assumed that the various grain areas delineated in Fig. 12 by the ends of the parallel markings represent crystals of homogeneous metal. Since hypo-eutectoid steel of such low carbon content could not be expected to develop such large areas of pearlite, one naturally wonders what has caused the entire suppression of the carbonaceous areas so prominent in the center of the weld (Fig. 14) and in the original stock (Fig. 13). Entire decarbonization of this cool, surface zone resulting in pure ferrite is not likely, since a study of butt welds

[2] Figs. 17, 18, 19, 20, 21, 27, 28 and 29 are from Howe, "The Metallography of Steel and Cast Iron."

shows that decarbonization depends upon degree of heat rather than proximity to surface. Furthermore, the decarbonization at a blow-hole is not deep seated nor complete, as is very evident from an examination of Fig. 11. Unquestionably the original carbon is still

ward rapidly while the high-temperature lines shrink into nothingness with even greater speed. Evidently some particular zone between the outmoving and inshrinking isotherms remain at about the same temperature for a comparatively long time. Fig. 25 shows



FIGS. 16—21, 26—29

Fig. 16—Transition from sorbitic to eutectiform structure in spot welded hypo-eutectoid steel; x 260. Fig. 17—Twinning striation of plagioclast. (Rosenbush); x 45. Fig. 18—Twins in copper; x 50. Fig. 19—Neumann bands; x 500. Fig. 20—X-Bands in ferrite after 30,000 lb. compression per sq.in. Fig. 21—Regular slip bands in ferrite; x 500. Fig. 26—Widmanstättian structure of ferrite; x 50. Fig. 27—Closely packed W-bands; x 80. Fig. 28—Eutectiform pattern in austenitic manganese steel; x 90. Fig. 29—Cementite assembled on grain boundaries and octahedral planes in manganese steel, showing subsequent agglomeration; x 50.

there and any explanation of the nature of the structure represented by Fig. 12 must account for its apparent disappearance.

Temperature During Welding

A study of the probable course of heating and cooling in the neighborhood of the spot welded zone may be useful at this juncture. Suppose the assembled plates to have been gripped by the welder dies and the current turned on. After a short time interval, say one-half second, the temperature gradient existing in the plates directly between the dies may be something like that sketched in Fig. 22. A few arcs carry the current across the narrow air gap, heating the metal intensely—locally to the fusion point. In the diagram two small arcs are shown, with a 1000-deg. isotherm back into the metal somewhat. The intense heat very rapidly radiates by conduction back into the metal, giving isotherms like that shown for 500 deg., the temperature gradient being steepest in the regions nearest the arcs. This radiating heat reinforces the Joule effect of the high amperage flowing through the iron resistance, and their combination forms a 100-deg. curve about as shown.

At the end of the next time interval, a number of localized arcs have effected the weld over a considerable area and the heat from the resistance offered by joint and metal have pushed the isotherms back to the approximate condition shown in Fig. 23. At the end of the third time interval the current is shut off, when the heat gradient is approximately as mapped in Fig. 24, since the weld is completed in a matter of a second or two. The hot interior, now robbed of its heating current, is rapidly quenched by its surrounding colder metal, the low-temperature isotherms still moving out-

this hypothetical condition at the end of the fourth time interval.

It is hardly necessary to sketch the location of the temperature lines further. Within a very few seconds the 500-deg. isotherm begins to contract and even the 100-deg. isotherm halts and reverses its direction, starting back to its origin. The main point is that there is formed a hot zone, flatly ellipsoidal in shape where the temperature is above the welding heat, and a larger, fatter ellipsoidal volume where the temperature has exceeded the transformation range momentarily or for some time. Immediately thereafter the hot center is "quenched" by radiation into the cold surroundings, the interior at a much higher rate than the outer fringe, which latter may well remain stationary in temperature for some time.

Austenite Crystals Fault Along Cleavage Planes

The austenitic spheroid, being directly between the dies of the welding machine, is under considerable compressive stress, but is unable to flow any measurable distance owing to its uniform side support by relatively rigid metal. Extrusion of a fin as in a flash weld (Fig. 3) is evidently impossible, but the highly stressed crystals of austenite develop their characteristic octahedral cleavage planes exactly similar to those accompanying the surface slip bands appearing in a polished surface after its underlying metal has been severely strained. On cooling through the transformation range the austenite tends to precipitate its excess ferrite—each crystal rejects the solute to its boundaries, hence the ferrite tends to gather along the cleavage planes. Thus, the central portion of the weld as shown in Fig. 14 is largely of dark-etching troostite or sorbite, but close

examination shows a well defined hair-like precipitation of the excess ferrite fringing many of the allotriomorphic crystalline boundaries, and numerous very fine, white, parallel striations crossing at 60 deg. appear in one of the dark areas near the center of the original micrograph. Very definite "fringes" of larger parallel ferrite needles extending inward from the grain boundary are shown in Fig. 15, near the edge of the sorbitic zone.

Just outside the darker-etching zone (in the region of eutectiform structure) a peculiar conjunction of pressure and temperature evidently occurred. During welding the temperature passed the transformation range, and the pearlitic areas passed into austenite. Migration of carbide to equalize the carbon content of these original austenitic crystals must have been extraordinarily rapid. The austenite crystals were at the same time fractured along their octahedral cleavage by the compressive stress of the welding dies, exactly as indicated in the discussion of the underlying dark-etching areas, and on cooling, after the electric current had been interrupted, each little lamina bounded by the parallel cleavage planes acted as an independent crystal in expelling ferrite to its surfaces. Hence the ferrite marks the sub-microscopic cleavage planes; or rather, the thinnest plate of eutectoid remains at the neucleus of each crystalline lamina. After polishing and etching, the eutectoid films etch dark as a series of straight lines crossing from boundary to boundary of the original crystalline entity. Evidently the process of extruding the ferrite from the original austenitic laminæ was just completed when the cooling of the zone in question prevented the further molecular mobility necessary for the agglomeration of the thin plates into balls of less superficial area, which is the normal appearance of low carbon steel (Fig. 13).

Widmanstattian Structure

Widmanstättian structure, cleavage structure, or more shortly W-bands (Fig. 26), were named in honor of their discoverer, who found them in meteorites over a century ago. W-bands appear often in steel castings, and according to Sauveur[2] the excess constituent of steels cooling rapidly through the transformation range will largely precipitate between the cleavage planes of the small octahedra composing each grain, "probably because the necessary time is denied for this excess constituent to reach the boundaries of the grains."

The eutectiform appearance has therefore been shown to be identical in nature with the W-bands—it consists of a concentration of excess ferrite along the octhedral cleavage of austenite. The straightness of the striations (extremely perfect in some grains) is indicative of crystalline cleavage, while in many small crystals intersections at 60 or 120 deg. may be observed. Indeed, toward the right of Fig. 12[3] one star-like burst of rays shows five of the six possible directions starting from one point. The W-bands developed in spot welding have little in common with the appearance of Widmanstättian structure as ordinarily illustrated (Fig. 26), but the close packed W-bands of Fig. 27 would appear quite similar on a lower magnification. Howe and Levy[4] observe the same general appearance in overstrained and

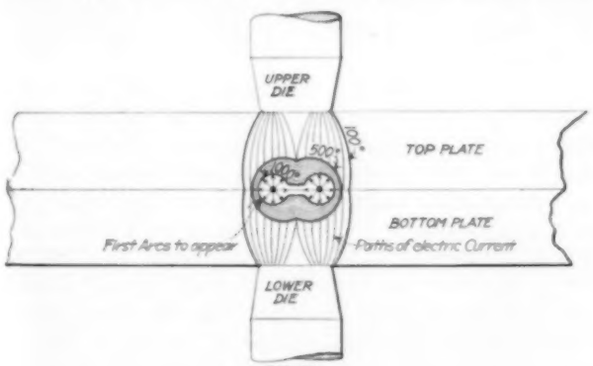


FIG. 22

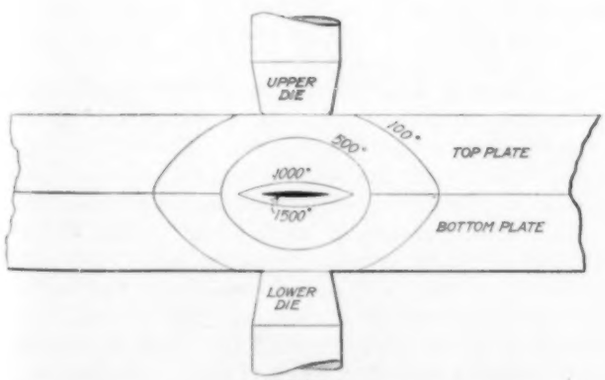


FIG. 23

Fig. 22—Ideal representation of temperature gradient in the spot welding operation shortly after the current is turned on.
Fig. 23—Location of isotherms at the termination of the second time interval.

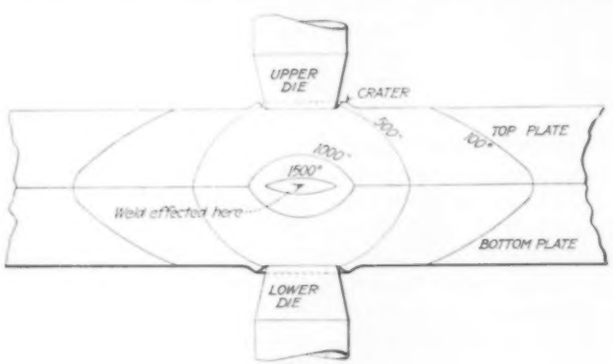


FIG. 24

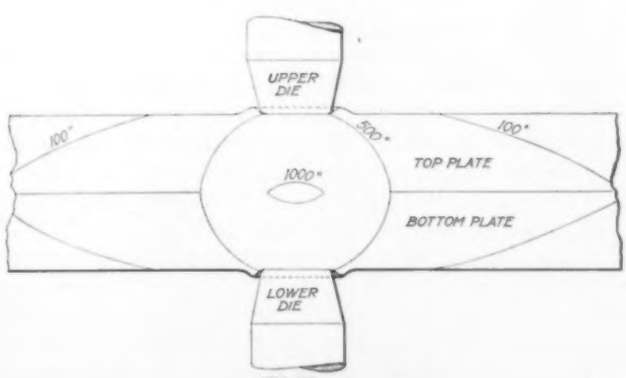


FIG. 25

Fig. 24—Location of isotherms at instant when weld is completed and the current switched off.
Fig. 25—Location of isotherms a very short time after welding is completed.

[2] "The Metallography and Heat Treatment of Iron and Steel," page 212.
[3] Beyond the edge of the half-tone and therefore not shown.
[4] *Trans.* A.I.M.E., Vol. 51 (1915), p. 881.

heated austenitic manganese steel (Fig. 28), caused by the same train of events, that is to say, first fracturing the original austenitic crystals of the quenched metal along their cleavage planes, and thus forming a multitude of new crystalline entities. Then on annealing below the transformation range, the sluggish austenite reverts slowly to beta and alpha iron, extruding the excess and now insoluble cementite to the cleavage—in other words, to the boundaries of each individual plate-like crystal. Further heating will agglomerate this extruded cementite into nodules as shown in Fig. 29 of such considerable size as to be indentified with certainty by differential etching.

PRACTICAL DEVELOPMENTS

Spot welding—two years ago a comparatively unknown process—has risen rapidly in favor, giving great promise of effecting enormous savings in money, time and labor in the fabrication of structural shapes, steel railway cars, and ships. In building structural members the plain pieces of plates, angles, and beams are clamped together in their proper relation and stitched together with a spot welder, one weld appearing in place of each rivet. The saving in templet-making, laying out, punching, reaming, and match assembly is obvious. In car bodies and crane runways especially, there are no rivets to work loose after the shaking impact and vibration of long service. The elimination of electrolytic corrosion between rivet and plate would be a determining factor in many cases which would decide in favor of a homogeneous spot weld.

The engineer will naturally pause, however, until sufficient and varied data have been accumulated to convince him that the new will not be inferior to the present method in strength and shock resistance. It is thought that the decarbonization and hardening effects occurring at the weld and so evident in the higher carbon steels will have little effect upon the efficiency of a mild steel connection.

Japanese Copper Industry

The refining and manufacturing of copper forms the most important native metal industry in Japan, the exportation alone amounting to about 100,000,000 yen ($49,800,000) per year. The classes of copper articles exported and imported for 1917 are given in the following table:

Articles	Exports	Imports
Ingots and slabs	$43,747,551	$1,791,428
Plates and sheets	682,352	.....
Wire	2,189,152	.....
Insulated electric wire	1,559,457	25,454
Manufactures	118,579	.....
Waste or old	.....	136,566
Other	1,525,210	19,419
Total	49,822,301	1,972,867

The ingots and slabs are imported from Korea, which, while a part of the Japanese Empire, has a separate customs administration. The waste or old copper consists principally of copper coins imported from China. Submarine cables, chiefly imported from Great Britain, constitute the greatest part of the insulated electric wire imported. The remaining imports, therefore, classified under the heading of "other," do not amount to more than $20,000 per year, and consist of small shipments of extra high grade wires, tubes, and miscellaneous articles. It can be readily seen that there is not a large market in Japan for American copper manufactures.

At present, owing to the decreased orders from Russia and the fact that the United States and many of the allied countries have set a price on copper below that at which the Japanese producers are willing or able to sell, there are large stocks of copper on hand. The present price in Japan is around 63 yen per 100 kin, which comes to about $23.60 per 100 pounds.—CONSUL ROBERT FRAZER, *Commerce Reports.*

Preparation of Belt Dressings

Many secret preparations of belt dressings, selling at a high price relative to the actual value of their ingredients, are on the market. In the main these consist of (1) mixtures of fats, waxes, tallow or degras with castor or other fatty oils; (2) vulcanized corn or cottonseed oil thinned with a solvent (gasoline or benzol); (3) preparations containing wood tar, and (4) preparations containing pine rosin, which should never be used, as gums cause the leather fibers to mat together and become brittle. Too frequent application of oils softens the leather and makes it flabby and stretchy. Of the natural occurring materials, beeswax melted in castor oil is the preparation par excellence, not having any tendency to gum up or rot the leather. About one ounce of naphthol or phenol to the gallon of this dressing will aid materially in preventing mildew from injuring belting in damp localities.

Where a good and less expensive dressing is desired, properly prepared vulcanized corn or cottonseed oil proves worth the time of getting the chemicals and making up. The production of a soft, spongy, rubber-like substance by adding from 18 to 25 per cent of sulphur chloride to rape oil was started on a commercial scale by Parkes in 1855 (British patent, Oct. 22, No. 2399). Leather oils based on this sulphur-oil product were first developed in America about the year 1889 by A. Sommer of the Viscol Company. If 17 per cent of sulphur chloride is added to corn, rape or cottonseed oil, the oil will rise about 70 deg. C. in temperature after about ten minutes of reaction and a very viscous, almost solid, gel will be produced.

In producing large quantities of this vulcanized oil, overheating is prevented by adding the sulphur chloride in parts at intervals, thus allowing the mixture more time to cool. After the reaction is complete, the product is treated with sodium carbonate, together with a small amount of a mixture of alcohol and benzol (50-50). All free acids are immediately neutralized by the alkali, but as there tends to be a slight splitting off of acid for a considerable period, a small amount of good tallow soap dissolved in alcohol should be added to introduce a permanent neutralizer. The viscous vulcanized oil is thinned with any solvent such as gasoline, benzol, carbon tetrachloride, etc., to give a dressing of the desired penetrating power.

In perfecting skill in vulcanizing oils, it is better for the uninitiated to work with small amounts of material until good results are a certainty. A dressing having sufficient softening properties, very good pulley grip and but slight tendency to be drawn out by dust, so that it is quite permanent, can easily be made in the plant laboratory by this method.

The Cottrell Processes in the Sulphuric Acid Industry

Description of Installations for the Removal of Dust from Roaster Gases and Acid Mist from Exit Gases—Successful Installations for Treatment at High Temperatures

By A. A. HEIMROD and H. D. EGBERT

THE Cottrell processes of electrical precipitation are today fully established in the metallurgical field as a standard means of removing from gases finely divided suspended particles of dust and fume, and as such they will be found in use in many of the largest smelters and refineries throughout the country.

But while this field of usefulness is well recognized it is not so widely known that these same processes are also today beginning to fill a long felt want in sulphuric acid manufacturing plants and seem destined to come into more and more general use in this important industry. It seems quite fitting indeed that this should be the case for it was while engaged in research work on sulphuric acid manufacture that Dr. Cottrell carried out the experiments in electrical precipitation which became the foundation of the processes which today bear his name. In fact it was a mist or fog of sulphuric acid particles which he first precipitated by means of a high potential unidirectional current, and it was for the precipitation of sulphuric acid mist that the first commercial electrical precipitation plant was installed.

Application in Manufacture of Sulphuric Acid

The Cottrell processes are today being used in sulphuric acid manufacturing plants for two different purposes: First, for cleaning the hot sulphur-dioxide-bearing gases after they leave the furnaces burning iron pyrites, zinc sulphide ores or other similar materials; and second, for removing and collecting the mist of acid carried by the exit gases coming from sulphuric acid concentrators or from the absorption towers in plants manufacturing the acid by a contact process.

It is the intent of this article to describe typical Cottrell installations designed by the Research Corporation for each of the above mentioned purposes, and in so doing it will be assumed that the majority of its readers need no explanation of the fundamental principles underlying the electrical precipitation processes. Those who may not be familiar with these principles or the terminology involved are referred to the literature on the subject[1] in which will be found a full discussion of the elements of electrical precipitation.

The problem of satisfactorily cleaning the sulphur dioxide gases prior to their oxidation and conversion into sulphuric acid has long been a troublesome one for acid makers to solve. In contact-acid plants it is of course essential that the gases be completely freed from suspended particles of dust or fume prior to their passage through the catalyst and it is almost equally desirable in the case of chamber plants that the sulphur dioxide gases be thoroughly cleaned if the plant is to operate at high efficiency and produce a clear acid of good quality. In the latter case, however, the problem is complicated by the fact that the sulphur dioxide gases must be cleaned at a very high temperature whereas in contact plants the gases can be cooled during the cleaning process or can be cooled first and then purified.

Sources of Dust Which Must be Removed

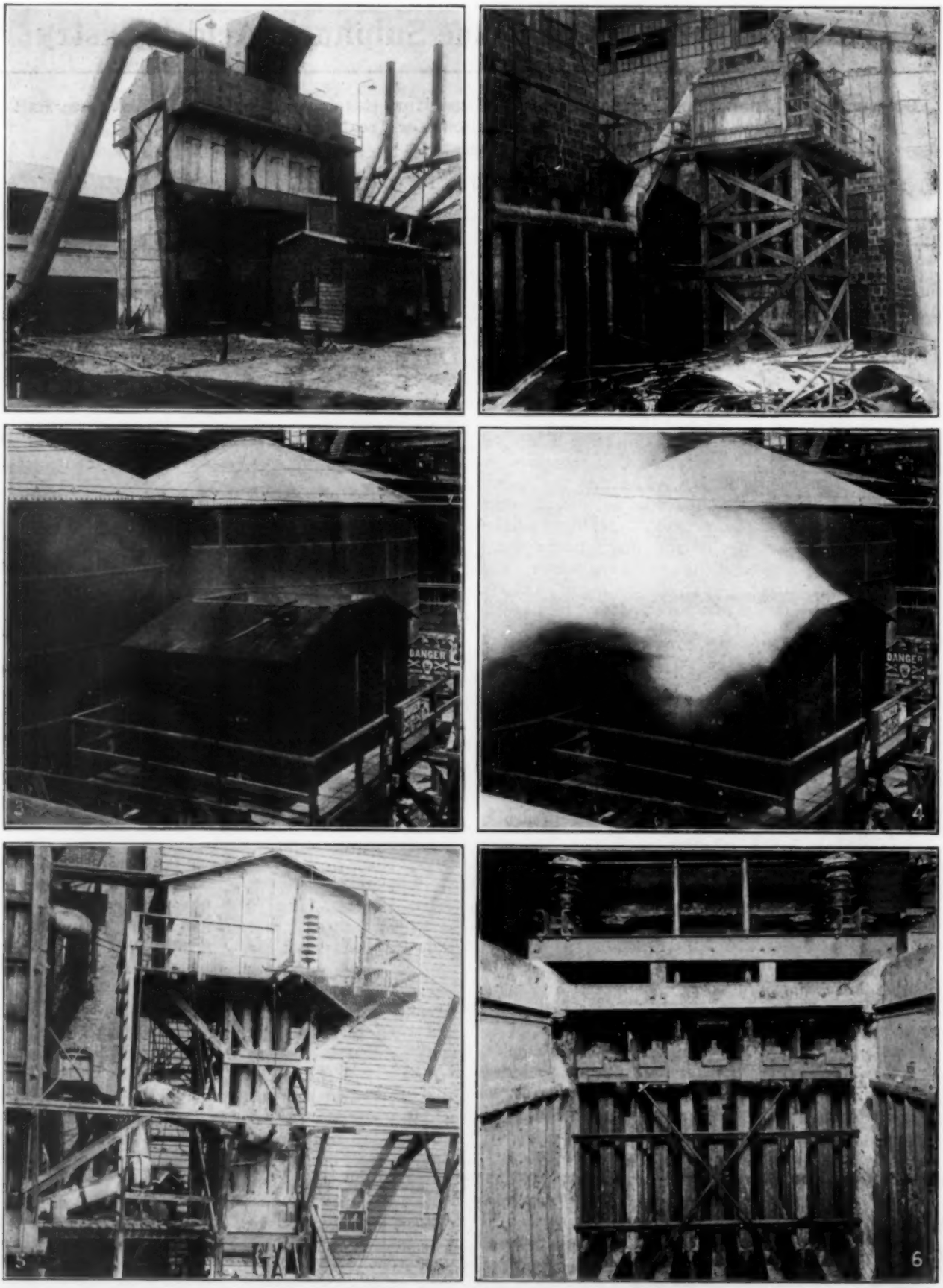
Aside from crude sulphur or brimstone, pyrites, pyrrhotite and zinc sulphide ores are the materials most widely used as the source of sulphur dioxide gases which are later by oxidation converted into sulphuric acid. The roasting of these materials, especially when they are in a finely divided form, gives rise to much dust which must be removed from the gases before their passage through the further stages in the process of acid manufacture.

It is common practice in most acid plants to use furnaces of the type in which the charge is continually agitated while being roasted, and this materially tends to increase the amount of dust carried over by the gases produced by such furnaces, thus making still more important the installation of some means of cleaning the gases. Of course when brimstone is burned the dust problem is eliminated since the gases coming from the burners are practically free from suspended particles of dust or fume.

War conditions have so interfered with the importation of pyrites that many plants are today burning sulphur which under normal conditions would use pyrites and they are thus for the present free from dust troubles. This is only a temporary situation however, and with the resumption of pyrites importation the cleaning of the gases as they come from the roasting furnaces will once again be a necessity. Plants now burning brimstone must therefore look to the future and they should take steps now to provide suitable means for cleaning their furnace gases, as will be necessary when pyrites are again available. Designers of new plants should leave ample space for the installation of suitable gas-cleaning system even though there is no present need for such apparatus because of the use of brimstone instead of other forms of sulphur-bearing materials.

In designing Cottrell precipitators for cleaning roaster-furnace gases the temperature at which the gases must be cleaned and the character of the suspended matter to be removed from such gases are gov-

[1] Problems in Smoke, Fume and Dust Abatement. By F. G. Cottrell —From the Smithsonian Report for 1913. Solution of Smoke, Fume and Dust Problems by Electrical Precipitation, by Linn Bradley—*Metallurgical & Chemical Engineering*, Vol. XIII. No. 15, December 1, 1915. Recent Progress in Electrical Smoke Precipitation. By F. G. Cottrell. Presented before the Second Pan-American Scientific Congress, Washington, U. S. A., December 27, 1915-Jan. 8, 1916.



TYPICAL INSTALLATIONS OF COTTRELL PRECIPITATORS

Fig. 1—Cleaning gases from zinc roasters. Fig. 2—Cleaning gases from sulphuric acid concentrators. Fig. 3—Removing sulphuric acid mist from exit gases; current on. Fig. 4—Same; current off. Fig. 5—Removing acid mist. Fig. 6—Interior view of equipment to clean hot roaster gases.

erning factors. Of course the size of the installation depends directly upon the volume of gas to be cleaned and this in turn is fixed by the quantity of material being roasted per unit of time and by its sulphur content as well as by the percentage of sulphur dioxide in the gases leaving the furnaces. These factors must therefore be known or approximated in order that a precipitation plant of suitable capacity may be provided. Two types of precipitators are today being installed for cleaning the hot furnace gases in sulphuric acid plants. These types differ widely from each other and the decision as to which type should be installed is based largely upon the temperature and fume or dust conditions to be met in the particular plant under consideration. In cases where the gases must be cleaned at temperatures of 1000 deg. F. and over, and where the suspended matter to be removed is mostly dust rather than fume, precipitators of the so-called "plate type" in which the gases pass horizontally between the collecting and discharge electrodes have proved highly satisfactory. On the other hand where the gases can be cooled before cleaning to a temperature of about 600 deg. F. or under and where the suspended matter to be removed is fume rather than dust, precipitators of the pipe type in which the gases pass vertically upwards between the collecting and discharge electrodes would in general be the most suitable.

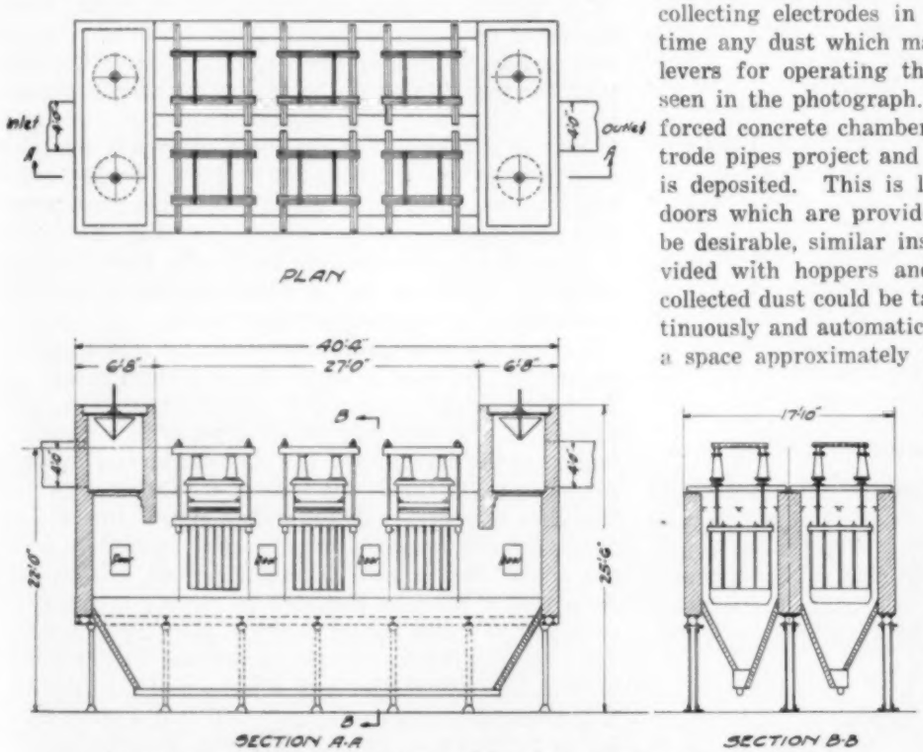


FIG. 7.—GENERAL ARRANGEMENT FOR CLEANING ROASTER GASES

Fig. 1 is a photograph of a Cottrell precipitator of the last mentioned type which was recently installed under the supervision of the Research Corporation at a plant in Wisconsin. Here the gases to be cleaned come from three Mathey rotary kilns, each roasting a little over two tons per hour of Wisconsin zinc ore concentrates having the following approximate analysis: Zn 30 per cent, Fe 30, Pb 0.75, S 35. The gases are cleaned at a temperature of about 500 deg. F. and will shortly be used for the manufacture of sulphuric acid by the contact method.

Cleaning Zinc Roaster Gases

With three kilns in operation the volume of gas passing through the precipitator at the above-mentioned temperature is 17,500 cubic feet per minute and there will be collected under such conditions about 7600 pounds of material per twenty-four hours having the following analysis: Zn 22 per cent, Fe 30, Pb 2.2, S 30.

The precipitator as installed consists of two units each having 36 collecting electrode tubes or pipes. These pipes are of steel, 12 in. in diameter and 15 ft. in height. The discharge electrodes are No. 10 jack chains suspended in the vertical axis of each pipe. Means are provided for rapping both the discharge and collecting electrodes in order to remove from time to time any dust which may have adhered to them. The levers for operating the pipe rappers may be clearly seen in the photograph. The bottom header is a reinforced concrete chamber into which the collecting electrode pipes project and in which the collected material is deposited. This is later removed by hand through doors which are provided for this purpose. Should it be desirable, similar installations could be readily provided with hoppers and screw conveyors so that the collected dust could be taken out of the precipitator continuously and automatically. This precipitator occupies a space approximately 17 ft. wide by 28 ft. long and has an overall height of about 35 feet. The electrical equipment provided for furnishing the high potential unidirectional current required by the precipitator consists of a 200 to 65/70 75/80/85,000-volt transformer operated directly from the plant power line, a mechanical rectifier driven by a 3-hp., 3-phase, 60-cycle synchronous motor also operated directly from the plant power line and a switchboard panel with the necessary instruments and control apparatus such as circuit breaker, rheostats etc. The amount of power required to operate the installation is about 18 kw.

Operating at a Temperature of 1100 Deg. F.

Fig. 7 is a drawing giving the general arrangement and overall dimensions of a precipitator of the horizontal-flow or plate type, designed and installed by the Research Corporation, and Fig. 6 is a photograph taken looking in a lengthwise direction through a precipitator of this kind which was installed in a chamber acid plant near Baltimore, Maryland, and which is particularly designed to withstand the high temperatures at which the gases must be cleaned in such a plant. This installation operates at a gas temperature of 1100 deg. F., while occasionally temperatures as high as 1400 deg. F. have been recorded in the precipitator.

A precipitator of the size shown in Fig. 7 will clean the hot gases produced by the roasting of 40 to 45 tons of fine pyrites per twenty-four hours. With a sulphur dioxide concentration of 7½ per cent to 8 per

cent this means that the volume of gas passing through the installation is about 17,500 cubic feet per minute at a temperature of 1100 deg. F.

The installation at Baltimore just referred to takes the gases from two 22-ft. diameter, 7-hearth Herreshoff furnaces, each of which burns from 20 to 25 tons of fine iron pyrites per 24 hours. Between 900 pounds and 1200 pounds of dust which is practically all Fe_2O_3 is collected per day by the precipitator. The iron content of the acid made with the Cottrell plant in operation is only 0.044 per cent.

As will be noted from an inspection of Fig. 7, the precipitation installation is divided into two sections each of which is provided with a damper at both inlet and outlet ends. This makes it possible to shut off either section from the system when inspection or repair is required or when it is desired to clean the electrodes as may be necessary every few days if a very dusty ore is being roasted in the furnaces. For the above reason it is desirable to so design the plant that each section will have sufficient capacity to handle all the gas for short periods of time and in this way, barring unusual accidents, continuity of operation with clean gas is practically assured.

It has been found by experience that cast-iron jug dampers give the most satisfactory service under the severe temperature conditions which are met with in installations of this character, and room for the installation of dampers of this type should be provided wherever possible.

Design of Electrodes for High Temperature Work

The collecting electrodes of precipitators such as are shown in Figs. 6 and 7 are heavy steel plates reinforced with angle iron stiffeners and suspended in parallel rows in a brick-walled chamber. The discharge electrodes are heavy steel strips or angle irons suspended midway in each of the spaces between the parallel collecting electrode plates.

The discharge electrodes are held in place by frames which are rigidly braced and fastened together at the ends. The frames are suspended from longitudinal T-shaped cast-iron members which in turn rest on transverse beams also made of cast iron but of rectangular shape and cast hollow. These transverse beams are themselves suspended by means of cold-rolled steel rods passing through the roof of the precipitator and supported by a framework carried on insulators placed above and outside of the precipitator. This type of construction is especially advantageous where high gas temperatures exist because the insulators which support the weight of the discharge electrode system are entirely out of the precipitator and thus are removed from all contact with the hot gases. They are therefore subject to no unusual strains and can be easily inspected and cleaned whenever necessary. Insulation must, of course, be provided at the points where the steel supporting rods pass through the roof of the precipitator. This is accomplished by the use of pyrex glass bowls or by oil lutes. In the latter case the oil which is the insulating medium also acts as a seal to prevent the inleakage of air at these points.

It is usual to design installations of this type to operate at relatively low voltages in order to simplify the insulation problem and for this reason a working voltage of only about 50,000 volts is used in actual practice.

The walls of the precipitator are of brick laid up in three courses in which fire brick, insulating brick and ordinary brick are used respectively. Outside of this is placed a steel casing which serves both to strengthen the walls and to prevent the inleakage of air. The entire precipitator structure is supported on heavy steel columns and is elevated to a sufficient height above the ground so as to allow for hoppers into which the dust falls as it is removed from the gases. The hoppers terminate in screw conveyors which serve to carry the collected material away from beneath the precipitator.

Small Power Consumption

The power consumption of installations of the above character operating on gases from furnaces roasting iron pyrites is usually quite small. This is the case with the precipitator at the acid plant near Baltimore which has just been described and where the power used is not over 2 kw. The electrical equipment provided at this plant consists of a 200 to 30/35/40/45/50,000-volt transformer operated directly from the plant power line, a mechanical rectifier driven by a 2-hp. 750-r.p.m. 3-phase, 25-cycle synchronous motor also operated from the plant power line and a switchboard panel with the usual control apparatus, instruments etc.

During the concentration of sulphuric acid a certain amount of acid mist is always formed which passes out from the concentrating system with the exit gases. The amount of mist thus carried off depends to a large extent upon the degree to which the concentrator is being forced as well as upon the type of concentrator in use. The mist, however, is almost always present in sufficient quantity to constitute a neighborhood nuisance even if the actual loss of acid is not a serious matter, and some means must be provided to remove it from the concentrator gases before they are discharged into the air. The installation of coke towers and similar scrubbing devices will remove only a portion of the mist and it is therefore not surprising to find that a large number of Cottrell precipitators have been installed and are today satisfactorily solving the acid mist problem in many sulphuric acid concentrating plants.

Removal of Mist from Exit Gases

Precipitators installed for this service are of the pipe type and must of course be constructed of acid-proof materials. Lead is almost always used for the top and bottom headers, while the collecting electrode pipes are of lead or tile as may be found convenient. Figs. 2 and 5 are photographs of two Cottrell precipitators which have been recently installed under Research Corporation supervision to remove the acid mist from the gases coming from sulphuric acid concentrators. Fig. 3 shows the effect of the high potential current on the cloud of acid mist which issues from a precipitator of this type when the current is off as seen in Fig. 4.

The precipitator shown in Fig. 2 treats the gases given off by three concentrators of the tower type producing together a total of about fifty tons of 66° Bé. acid per twenty-four hours. About 3000 cubic feet of gas per minute at a temperature of 135 deg. F. passes through the precipitator and from this is collected about

3000 pounds per twenty-four hours of 18° Bé. acid. The draft necessary for the proper operation of the concentrators is provided by a fan placed between the concentrators and the precipitator and also to a certain extent by a stack to which the gases pass after leaving the precipitator.

One Cottrell unit is provided which has 16 collecting electrode pipes built of sectional tile with joints set up in acid proof cement. All of the pipes are 15 ft. in height and all are 12 in. in diameter with the exception of two of the corner pipes which have a diameter of 16 in. These are made larger to provide for the larger

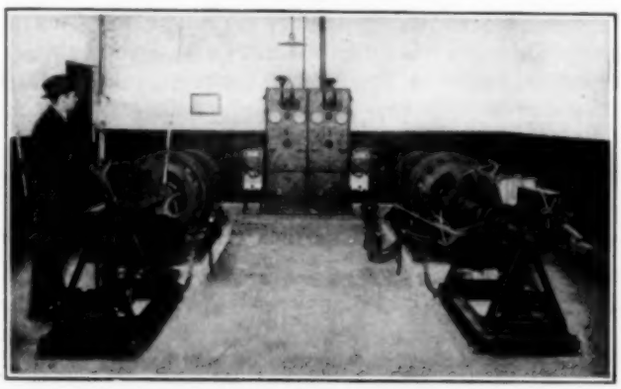


FIG. 8.—TYPICAL INSTALLATION OF ELECTRICAL APPARATUS

and rigid discharge electrodes which are placed in the corner pipes and which serve to hold steady the entire discharge electrode system. The discharge electrode in each of the other fourteen pipes is an iron wire enclosed in a thick star-shaped lead casing. The top and bottom headers of the precipitator are of lead and with the pipes are supported on a timber framework.

Dampers of the jug type are provided and are so arranged that the gases from any one or all of the three concentrators can be shut off from the precipitator at will. Furthermore provision is made so that all the gases can be by-passed around the precipitator to the stack should it be necessary to shut down the installation for the purposes of repair etc.

Insulators Must Have Large Safety Factor

In Cottrell installations for the collection of acid mist great care should be taken with the insulators supporting the high potential parts of the precipitator. Insulators with a large safety factor as regards voltage rating must be provided and they must be well protected from the acid fumes. In practice it has been found best to depend on the stiffness of the lead covered discharge electrodes to prevent them from vibrating and to provide no insulators in the bottom header of the precipitator. The insulators now generally used in the top header to support the discharge electrode framework are of the corrugated post type made of one piece of porcelain and covered with hoods to protect them as much as possible from the deposition of acid or moisture.

The electrical equipment provided for the installation just described consists of a 5-kva. 200 to 65/70/75/80/85,000-volt transformer operated directly from the plant power line, a mechanical rectifier driven by a 3-hp. 1800-r.p.m. 60-cycle synchronous motor and a switchboard panel with the necessary control apparatus. The precipitator operates at a potential of 75,000 volts and the power consumption of the installation is about 3½ kilowatts.

The precipitator shown in Fig. 5 cleans 2500 cubic feet of gas per minute at a temperature of 200 deg. F., coming from two concentrators of the tower type producing a total of forty tons of 66° Bé. acid per twenty-four hours. This installation collects approximately 3500 pounds per twenty-four hours of acid having a concentration of 33° Bé.

There is one precipitator unit supported on a timber framework and having twelve collecting electrode pipes each 12 in. in diameter and 15 ft. in height. The pipes in this case are of lead as is also the bottom header. The top header is of frame construction lined with lead. Lead covered iron wire is used for the discharge electrodes. The electrical equipment is of the type previously described and is housed in a small frame building placed close to the precipitator.

Cleaning 30,000 Cubic Feet of Gas Per Minute

One of the largest precipitation installations now in service for the removal of acid mist arising from sulphuric acid concentrators is that which was recently installed to clean the waste gases from twenty-two concentrators of the cascade type, each having a rated output of ten tons of 66° Bé. acid per twenty-four hours. The volume of gas cleaned averages thirty thousand cubic feet per minute at 180 deg. F. and there is collected some twenty-five tons of 40° Bé. sulphuric acid per day. The precipitator consists of four units, each having twelve collecting electrode pipes 12 in. in diameter by 15 ft. in height. The precipitators are constructed of lead throughout and are supported on a timber framework. One set of electrical equipment of the usual type furnishes the power acquired by the installation, switches being provided in the high voltage line so that any precipitator section can be disconnected at will. In the case of each of the installations which have just been described fans placed between the precipitator and the concentrator are used to create the necessary draft.

Steam Jets Used to Induce Draft

In some instances steam jets have been used for this purpose but these are not as satisfactory and the acid reclaimed by the precipitator is in such case of a much lower concentration due to the condensed moisture from the steam jet which is precipitated with the acid mist. That portion of the steam which is not condensed prior to passage through the precipitator is, of course, not removed from the gas but passes out and condenses on being discharged into the cooler air. Thus the usual clearance obtained by a precipitator treating the gases from a concentration system in which steam jets are used as a source of draft is not complete, due to the cloud of condensed steam produced at the precipitator exits. The acid mist, of course, is completely removed in either case.

In plants manufacturing sulphuric acid by the contact process there is often a considerable amount of acid mist escaping from the absorption towers, especially when the plant operating conditions are abnormal. When the plant is located near a residential

or in a highly cultivated agricultural district the mist escaping at such times may be a cause of considerable nuisance or damage to surrounding property owners. In such cases also the Cottrell processes have been successfully applied for the removal and collection of the acid mist from the exit gases.

There are still other points in the process of sulphuric acid manufacture where the Cottrell processes of electrical precipitation might be applied with interesting results leading to additional economies and improvements in operation, and experiments are about to be conducted by the Research Corporation looking toward further development along these lines in the near future. The cleaning of the roaster gases and the removal of acid mist from concentrator and absoption tower exit gases is, however, an established commercial use of the Cottrell processes and one in which they are coming more and more into universal use.

Research Corporation, New York City.

Conservation of Technical Engineers

TECHANICAL engineers of every branch of the profession who are taking part in the war activities of the Army and Navy are alarmed at the unfortunate waste of technical training caused by the drafting and enlisting of engineers for regular service with little or no regard for their technical attainments. These technically educated and experienced men are essential to the successful conduct of the war and cannot be replaced. There is continuing evidence that America is repeating in some measure England's mistake of sending technical men into the ranks when they should be carefully conserved for special duties in the fighting forces or on the technical staffs of the Army, the Navy and the essential war industries.

These facts have been forced upon the attention of engineers who have been co-operating with the Government through the Naval Consulting Board, the National Research Council and Engineering Council. Upon these organizations requests have constantly been made for engineers, chemists and other technical men for a great variety of military services. Thousands of names have thus been furnished to the Government departments and bureaus. Engineering Council especially has devoted attention to this personnel work through its committee, known as American Engineering Service, which has available classified lists of approximately 25,000 engineers, and besides unclassified lists of many more. It is from these lists, directly or indirectly, that most of the names have been selected for war service.

Engineering Council was founded by the American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers; and other engineering societies are co-operating with it in this service, the total membership represented by these organizations being approximately fifty thousand. Already from *10 to 15 per cent of the members of these several organizations are in the uniformed services of the country* and it is safe to say that a large majority of their remaining members are in the Government civilian service or otherwise directly or indirectly engaged in the War. Engineers do not seek to avoid fighting, but earnestly desire to be given opportunities for fighting and other services in which they can be most effective and which cannot be performed by others.

It is known that through the Committee on Classification of Personnel in the War Service Exchange (of the War Department) and some other ways, efforts are being made to counteract the tendencies toward the loss of our technical men in the ranks of the Army and Navy. It is believed, however, that these efforts are insufficient and that they should at once be supplemented by other stringent measures dealing with the subject in the Draft Boards and recruiting stations.

In view of the foregoing, Engineering Council, created to provide means for united action and to speak authoritatively for its member societies on all public questions of common interest to engineers, respectfully offers the following:

WHEREAS, technically trained engineers are indispensable to the Army, the Navy and the war industries, in engineering corps, ordnance bureaus and signal corps, in aviation, submarine and tank service, in shipbuilding, and in many other assignments; and

WHEREAS, through draft and otherwise many of these irreplaceable men have been and are being diverted so that their special qualifications are not being utilized, be it

Resolved, that in the opinion of Engineering Council technically trained men of all ages should be enrolled and conserved for technical duties, and special efforts should be made immediately by the War and Navy Departments to find and record such men among drafted and enlisted forces and to assign them to places in which their special qualifications are needed, and be it further

Resolved, that Engineering Council offers to assist the War and Navy Departments in locating and classifying such men, if its assistance be desired, provided these departments will give the necessary facilities for collecting information about engineers now in the Army and Navy, or whose names are upon the selective draft lists.

These resolutions are offered solely in a patriotic spirit of helpfulness. They are published here with the assurance to the Secretaries of War and the Navy that the resolutions have our hearty approval and are worthy of favorable consideration.

Japanese Coke Production

The statistics on metallurgical coke for the past year are published by *The Chemical Technology* of Tokio as follows:

	Tons
Government Iron Works	365,000
Mitsu's Miike	100,000
Tokio	80,000
Osaka	48,000
Makiyama	40,000
Shosho Yoko	40,000
The Kamedo	30,000
Munakata at Osaka	24,000
Asahi at Fukuoka	20,000
Yamashita at Osaka	15,000
Yamashita at Nagasaki	15,000
Yoshio at Tukuoka	10,000
Matsushima at Nagasaki	10,000
Iika	3,000
Total	800,000

The Metallography and Heat Treatment of Metals Used in Aëroplane Construction—IV

Uses of Copper and Its Alloys in Aeroplane Construction—Requirements for Sheets and Tubes—Details of the Brazing Process, Methods of Heating, Fluxes and Preparation of Parts

BY F. GROTTS
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COPPER

COPPER is used as tubing for gas lines and in sheets for tanks and propeller tips. The average chemical analysis is about 99.80 per cent Cu.

Copper sheet should be free from buckles, seams, discolorations and capable of being bent flat without cracking. In order to meet the bend test annealing is sometimes necessary. Annealing consists in heating the copper to such a temperature as will give the required softness and then quenching in water. In most cases 1000 to 1100 deg. Fahr. have been satisfactory temperatures for annealing.

PHYSICAL PROPERTIES RAW STOCK

	Tensile Strength, Lb.	Elongation, %
Soft	30,000	25
Hard	35,000	18

In the following experiments on annealing it is noticeable that the ultimate tensile strength remains nearly constant while the yield varies inversly with the increase of temperature:

Temp.	Time, Min.	Quenched, or Cooled	Tensile Strength, Lb.	Yield Point, Lb.	Elongation, Per Cent
600	30	H_2O	31,200	14,740	40.5
600	30	Air	30,000	13,300	43.0
800	30	H_2O	30,900	12,080	47.0
800	30	Air	32,150	12,700	45.8
1,000	30	H_2O	31,200	11,740	46.2
1,000	30	Air	31,000	10,800	46.8
1,200	30	H_2O	31,450	9,900	48.0
1,200	30	Air	31,700	10,000	47.0

FAILURES DUE TO FAULTY WORKMANSHIP

Several cases of copper sheet failing have been found. They were noticed because of gasoline leaking out. Examination showed fine cracks extending out from the soldered joints, as shown in Fig. 89. These fine cracks were due to faulty workmanship, and the vibration from the motor caused the copper to give way.

By faulty workmanship is meant cases where the solder is allowed to flow out in jagged points from the joint. It creates a stiffness which will localize any vibration. Ofttimes the tanks are so designed as to cause certain parts to be subject to unnecessary stress. Copper under stress will soon fail when subjected to excessive vibration. It was thought by some to be necessary always to solder copper joints with soft solder or silver solder, but brazing material works very nicely, especially for tubing.

Joints between copper and brass can be made with brazing material, but solder or silver solder is safer, minimizing danger of burning the brass.

Sheet copper on propeller tips often fails because of mashing or straining in tacking on. Dents from hammers start cracks, and because of the speed of the propeller these open up. Many cases have been reported as crystallization in the copper from the rapid motion, but to date such a failure has not been found here. Such examples have been found to start from either excessive or careless hammering, or straining the copper sheet in place.

The use of the blow torch on copper tanks should be discouraged because of danger of gassed copper, illustrated in Fig. 90.

The reducing element, hydrogen, of the torch combining with oxygen forms water. This water which is immediately converted into steam forms hair cracks which grow rapidly when stressed or vibrated.

TESTS FOR COPPER TUBING

Copper tubing for gas lines, etc., as made from cast ingots: This is hot-pierced and rolled, then finished by cold-drawing to the desired strength. This material is given three tests:

Flattening test—A section of tubing two inches long is flattened with a hammer until it will pass through a micrometer set to three times the thickness of the tube wall; no cracks should appear.

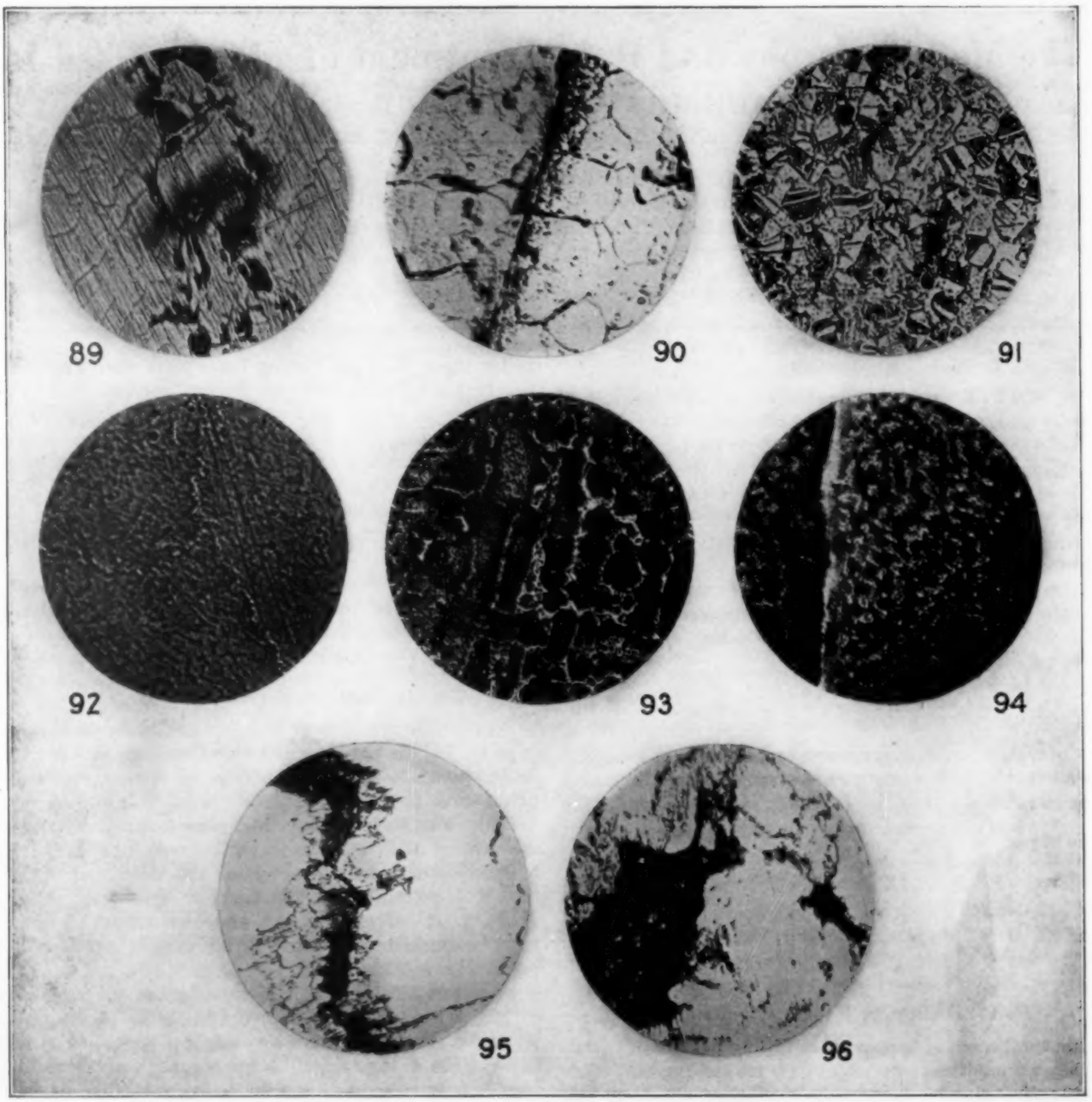
Crush test—A section one and one-half inches long must be crushed endwise to half its original length without cracking.

Bend test—Tubing as it is must be bent at an angle of 180° with a radius of half the thickness of the wall. Annealed specimens taken from the tubing should not crack when hammered to a fine edge. Joints in this materials were for a time only made from silver solder, as there were many cases of burned tubing. Brazing material makes a good joint and is much cheaper. The temperature necessary for successful brazing is not high enough to spoil any tubing. As copper tubing is bent into many shapes it is necessary to anneal it. The following tests were made on copper tubing of an analysis of 99.87% Cu.

Temp.	Time, Min.	Quenched	Ultimate Strength, Lb.	Yield Point, Lb.
400	30	H_2O	35,700	15,350
600	30	H_2O	35,250	13,430
800	30	H_2O	35,600	12,980
1,000	30	H_2O	33,200	9,130
1,200	30	H_2O	33,400	8,940
1,400	30	H_2O	34,000	7,630
Raw stock	..	....	28,600	14,950

BRASSES AND BRONZES

Brasses and bronzes give lots of troubles, as the material ofttimes is internally stressed by cold drawing to get a high tensile strength. These stresses are not shown by chemical analysis, physical tests nor microscopic examination. Machining, temperature variations,



FIGS. 89-96

Fig. 89—Fine crack in copper sheet, extending from soldered joint. Fig. 90—Gassed copper resulting from use of blow torch. Fig. 91—Tobin bronze before treatment with mercurous nitrate. Fig. 92—Tobin bronze after treatment with mercurous nitrate. Fig. 93—Manganese bronze. Fig. 94—Film of oxide in brass bar. Figs. 95 and 96—Cracks resulting from over-heating

corrosive agents, vibration, will cause the strains to become cracks. These cracks are sometimes called season cracks. They are peculiar to brasses and bronzes of less than 80 per cent copper. This type of alloy has a greater percentage of the brittle copper-zinc constituent than where the material runs over 80 per cent copper.

Annealing helps to remove these stresses and increases the elongation. The average temperature in annealing is about 700 deg. and the quenching is done in water. Water-quenched material seems to give more even results than air-cooled.

Tobin Bronze

Tobin bronze used for turnbuckles has an average analysis of 60.24 Cu, 0.67 Sn and 38.59 Zn. In order to remove stresses and meet specifications it is annealed at different temperatures.

Temp.	Quenched or Cooled	Tensile Strength, Lb.	Yield Point, Lb.	Elongation Per Cent	Reduction, Per Cent
400	H_2O	69,000	13,450	28.5	54.8
400	Air	69,500	13,340	29.5	55.6
600	H_2O	67,400	12,750	30.2	58.8
600	Air	68,000	13,140	26.0	57.9
800	H_2O	65,400	13,140	36.5	53.6
800	Air	66,500	12,980	35.0	37.8
1,000	H_2O	58,900	11,420	46.0	61.1
1,000	Air	39,800	11,500	44.0	60.0
1,200	H_2O	60,500	11,000	45.0	62.4
1,200	Air	60,000	11,150	42.0	61.5

Extensive investigations have proved that turnbuckle barrels when made from stressed bronze will crack when exposed to corroding agents such as ammonium hydroxide and sodium chloride. These failures nearly always trace their origin to trying to get a high tensile strength from drawing. This places the material in a strained condition and the cracks will appear during machining

or when subject to corrosion. It is interesting also that a turnbuckle barrel will sometimes pass inspection and then it will show up with large cracks seemingly from no cause whatever. In order to detect these internal strains a section about two inches long is taken from each rod, cleaned and polished and then immersed in a solution of mercurous nitrate (65 g. $HgNO_3$—15 cc. HNO_3—900 cc. H_2O) for twenty minutes. At the end of that time they are cleaned off and examined. The failure from the stressing will appear at once. The photographs reproduced in Figs. 91 and 92 show the material before and after being in the mercury solution.

Impurities often found are As, Sb, Bi, Fe and Pb. Arsenic is not so detrimental as Sb or Bi, which makes the material brittle, due to the fact that they will not form a solution but form thin layers between the crystals. A small quantity of iron (0.09) is not detrimental. Lead occurs in the Zn as minute globules.

Manganese Bronze

Castings are made from lake or electrolytic copper and spelter. This spelter has an analysis of

Pb 0.15, Fe 0.03, Cd 0.15, and Zn remainder.

The castings should be free from blow holes and spongy spots.

The average physical properties are tensile strength, 70,000 lb.; yield point, 30,000 lb.; elongation, 15 per cent. Chemical analysis, 59% Cu, 40 Zn, 0.15 Pb, and 3.0 Sn, Fe, Mn, and Al.

Several cracked sections were found that were caused from the welding in of a part. The strains produced by such an operation can be relieved by subsequent annealing.

Gun Metal

Gun metal is made from lake or electrolytic copper (99.88) and pig tin (99.0). It is used for instruments and finishings. It has an average chemical analysis of 87.5% Cu, 10.0 Sn, 2.0 Zn, 0.2 Pb and 0.15 Fe.

Physical properties: ultimate tensile strength, 30,000 lb; yield point, 15,000 lb.; elongation, 15 per cent.

Monel Metal

Monel metal is used for sheathing of aëroplane propellers. It is cold-rolled and should be clean and of uniform color. It is subject to a bend test, that is, hammered double without cracking. It has been remarkable because of the small number of flaws and defects found.

The average chemical analysis is:

Cu 25%, Ni 66, Fe 3.5, Mn 3.5, Impurities 1.0.

Physical properties: Ultimate tensile strength, 70,000 lb.; yielded point, 35,000 lb.; elongation, 25 per cent.

Brass

Bearings, bolts, nuts and brazing wire are made from brass. Bearings are made from yellow brass which has an analysis of Cu 64.5, Zn 34.8, Pb 3.2, impurities 0.37

Defects found are principally in the form of spongy spots and inclusions.

Bar brass for nuts and bolts in the raw state has the following physical properties: Tensile strength, 65,000 lb.; yield point, 42,500 lb.; elongation, 22 per cent; reduction, 48 per cent.

Chemical analysis: Cu 60.1, Sn 0.45, Fe 0.08, Pb 0.22, Zn remainder.

One bar was rejected because of a thin film of oxide shown in Fig. 94. This flaw showed up when machining and was probably due to carelessness in casting. Oxide was not all removed and afterward showed up in the bar.

Fluxes for Brazing Brass

Joints are made in tubing and sheet-steel by brazing. The parts to be joined should be carefully cleaned in order that the brazing material may have a good surface to adhere to. Fluxes such as borax are used to do away with any oxides formed.

The sheet or tubing should not be sandblasted before brazing as the material will not flow readily and overheating of both steel and braze sometimes results.

There are two brazing materials used, one having an an analyisis of 80% Cu, 0.3 Pb, 0.1 Fe, 1.25 impurities, Zn remainder; and the other having about 58 to 60% Cu and 40 to 42 Zn.

The first is preferable as the steel can be heat-treated afterward without damage to the braze.

Ammonium chloride, zinc chloride and sodium chloride (salt water) will sometimes give a reddish brown appearance to the braze. This indicates a slight dezincification, which means the braze is spongy and weak. Failure has been know to result from such joints.

Consideration of the Brazing Process

Brazing is a method of joining the parts of higher-fusing metals, usually steel or copper, by the use of a lower-fusing copper-zinc alloy, usually called "spelter," or in the case of steel or iron parts, of copper alone.

The parts to be joined are heated a little above the fusing point of the metal used to make the union, a substance applied, called a flux, which will fuse and dissolve all the metallic oxides present, and the brazing metal applied in such a manner that it will melt and flow into the spaces where the union of parts is desired. The parts are then allowed to cool in air, after which the joint is finished by removing the adhering flux and the superfluous brazing metal.

Brazing is sometimes referred to as "hard soldering," in distinction from "soft soldering," in which the uniting metal is a tin-lead alloy.

When a silver alloy is used as the uniting metal the process is called "silver soldering."

There is no single term which includes all of these methods.

In the brazing process the following items should be considered:

Composition and character of the brazing metal
Methods of heating parts
Composition of the flux
Preparation of the parts for the process
Cleaving the joint after being made
Effect of the process upon the metal of the parts joined.

Brazing metal—The "spelter" commonly sold in the trade is a "low brass," i.e., a brass having a comparatively low copper content, the object apparently being to keep the melting point as low as possible. The copper content should never be less than 55 per cent, as any further reduction very rapidly weakens the alloy.

The ultimate strength of a brazed joint clearly depends upon the strength of the brazing metal forming the union. Other things being equal, therefore, the metal

having the greatest strength should be used; but there are several conditions which affect the choice. This is the attraction which causes a liquid to "wet" a solid. In the case of brazing the attraction of the molten spelter for the iron, or other metal of the joint, exceeds that of the flux, so that it attaches itself to the other metal. There must also be no physical obstruction to this wetting action.

It is probable that there is a superficial alloying of one or both metals in the spelter with the iron, which forms the actual union, since the adhesion of the spelter to the iron is always stronger than either the iron or the spelter. In testing butt brazes of mild-steel rods either the brass or the steel parted; the brass never separated from the steel.

The "flow" of the spelter depends upon the wetting attraction, and the absence of physical obstructions. The chief physical obstruction is metallic oxide which forms on the surfaces of the heated metals, especially upon the surface of the molten brazing metal. Unless the oxides formed are instantly dissolved in the flux they form a film on the surface which prevents the union of the metals. It is highly important, therefore, that the brazing metal contain no metal whose oxide is insoluble in the flux used.

Fluxes.—The most satisfactory fluxes for brazing with copper-zinc alloy are borax, and boric or boracic acid. The latter is preferable because it contains no water of crystallization and melts down without frothing. Borax contains a large amount of water of crystallization, which is driven off in the first heating, causing it to froth violently, which causes it to be blown off by the torch or blast flames.

Iron, copper, and zinc oxides are freely soluble in molten boric acid, forming their respective borates.

Tin and aluminium oxides do not form borates. The presence of these metals in brazing spelter must therefore be considered as deleterious impurities; they interfere with the flow, and if in any considerable quantity provent it altogether.

Copper and brass have the peculiarity of dissolving their own oxides, and these will interfere with the flow of the metal. Brazing spelters should be clean metal, i.e., free from dissolved oxides, and impurities in suspension.

In practice a brass having a higher copper content than that usually given as having the greatest tensile strength was found to make the strongest joint. The best results were obtained with a brass having practically the composition specified by the Signal Corps, viz:

	Per Cent
Copper	78 to 82
Lead (maximum)	0.3
Iron	0.1
Total impurities	1.25
Zinc	Remainder

Experiments indicate that the iron content can be considerably higher than the amount given above without harm, while the maximum of allowable impurities appears high. But brazes made by the acetylene torch with metal containing 83 per cent copper showed a greater tensile strength, in a number of cases, than the steel, the joint holding while the steel parted.

Brazing metal is changed in composition and, where the acetylene torch is used, may be changed in crystalline structure, by the process. In gas-fire brazing it loses about 2 per cent of zinc, and in acetylene brazing it may lose as much as 6 per cent. The difference in color cannot be due to the change in composition, since brass of the same composition is pure yellow; it is probably due to a difference in the nature of the solid solution forming the alloy, the pink tint arising from the presence of beta crystals. This theory would also account for the considerably greater strength of joints brazed by the acetylene torch. The difference in crystalline structure is clearly shown in the micrographs of the braze of acetylene and fire-brazed joints.

Pure copper is inferior to good brass as a brazing metal. It requires a considerably higher temperature, with increased labor and danger of burning the steel, does not flow as well, and the finished joint is weaker.

Methods of Heating—The essential in making a good brazed joint is to have the parts of such a temperature that the brass flows freely, but not hot enough to "burn" the metal. This requires special care in the use of the acetylene flame in cases as light-gage tubing. Cases were found in which the tubing had been melted through and the hole covered with spelter. On the other hand, if the temperature falls too near the freezing point of the brass it forms a coarse, granular, brittle structure, thus weakening the joint. The intense heat of the acetylene flame tends to produce bubbles in the braze, probably by the rapid evaporation of zinc. This can be avoided, or reduced to a minimum, by taking a little more time and not trying to force the heating.

The acetylene flame produces the strongest joint, the gas-fire the next best, and dip-brazing the weakest. The weakness of the dip-braze is no doubt due to the fact that, as ordinarily practiced, the steel does not become any hotter, and possibly not as hot, as the molten brass. Dip-brazing should, therefore, be used only for joints in which there are large contact surfaces, such as reinforcements of tubing, and similar constructions. The average increase in strength of acetylene-brazed joints over fire-brazed in a series of experiments was 8.5 per cent.

Preparation of Parts—Steel parts should be free from adhering foreign matter, and from scale; the ordinary film of oxide does not matter. Sand blast should never be used to clean joints before brazing. The rough surface produced greatly interferes with the flow of spelter; and in the effort to overcome this, the workman overheats the steel, with the result that cracks, both in the brass and the steel, develop on cooling. Figs. 95 and 96.

The supposition that sand adheres to the steel and prevents the flow of spelter is erroneous; microscopic examination of the surface showed it to be perfectly clean. The effect is entirely physical. Where the size of the parts would admit they could be very effectively cleaned by tumbling with sand or other suitable material, which would leave the surfaces smooth and polished. "Pickling" with acid is unsafe, as it is very difficult to so completely remove the last traces as to prevent subsequent corrosion.

Parts to be united are held together either by pinning, or "tacking" with welds made by the acetylene torch. Pinning is generally used in assembling parts with tubing. Pins should be cut flush and "set" by spot-welding

the ends with the acetylene torch. Except where they are very large it is difficult to rivet them as they buckle in the tube. If left without being set they are of no practical use after the joint is finished, whereas they would form a large factor of safety if welded. Where joints are assembled by tacking, care should be taken to make the welds as small as possible; if large welds are made the lumps of iron left interfere with the filing of the joints after brazing.

Joints formed by crushing parts together while red hot, as in forming eyes on the ends of tubing, contain so much scale that it is not dissolved out by the flux, and therefore the spelter does not flow into the spaces where union is desired. In such cases the joint should be dipped in spelter and crushed into shape by a die press while the spelter is still fluid. This would insure complete union of parts, and save one operation. Where fillets are to be made the piece must be held so that the natural flow of the spelter will make a fillet of equilateral section. If the piece is not so held the fillet will spread out on one side and draw away from the other, causing extra labor to fill up the joint, and leaving a poor job in the end. A vise having a universal adjustment should be used for holding pieces that are to have fillets put in.

Cleaning Brazed Joints—Cleaning a brazed joint involves removing the black iron oxide, or scale, the fused borax, and the excess spelter. Sand blast affords a perfectly satisfactory method of removing scale and flux, except where brazing must be done afterward. For removing excess spelter a small electric or pneumatic hammer, fitted with suitable chisels, would do quicker and better work than filing. Power emery belts, properly arranged, can do most of the work of polishing after the excess spelter has been removed. Where sand-blasting is not feasible the borax can be removed with hot solution of carbonate of soda, which has no bad effect upon either the brass or steel.

Effect of the Brazing Process on Steel—The temperature required to melt brass is sufficient to anneal the steel to which it is applied. If the steel has been "tempered" by cold-working such as rolling or drawing, the effect is to increase ductility and reduce tensile strength.

Coke Prices Reduced

Reciting the fact that contracts for high-priced coal have generally expired, that the supply of coal is more regular and that the price of coal has been reduced ten cents a ton, an order has been issued by the U. S. Fuel Administration making a flat reduction of 30 cents a ton for coke produced in by-product ovens except in the states of Alabama and Washington. The order became effective seven o'clock a. m., September 3.

Under the order the base price for by-product coke is fixed at $5.70 for run of ovens and $6.70 for selected foundry, which is a reduction of 30c. per ton from the former base price. Except where otherwise provided, the maximum prices, f.o.b. cars at point of production, for each grade of by-product coke shall be the sum of the base price for such grade, and the freight rate from the competing bee-hive coke district which takes the lowest freight rate to the point where such by-product coke is produced.

The Terry Differential Flotation Process

THE Terry differential flotation process disclosed in U. S. Letters Patent No. 1,254,173, Jan. 22, 1918, and Canadian Patent No. 184,193, May 7, 1918, is based on the discovery that ammonia in solution promotes oxidation of metallic sulphides by air introduced into the pulp. An experiment illustrating the oxidizing influence of ammonia may be made by wetting clean pieces of iron with water and with ammonium hydroxide. Yellow ferrous carbonate soon forms on the iron wet with water while the piece of iron wet with ammonium hydroxide becomes bright red with ferric oxide. As the oxides of zinc, copper and lead are soluble in ammonium hydroxide and most ammonium salts, these sulphides are cleansed and their flotability is unimpaired, whereas iron oxide is insoluble and the oxide-filmed iron sulphide (pyrite or pyrrhotite) is rendered immune to flotation. As the air drives ammonia out of solution a closed tank and circulation system is the most economical in which to carry on the oxidizing reaction and conserve the volatile ammonia gas.

Fractional Percentage of Ammonia Required

The amount of ammonia required to accomplish this result depends on the character of the ore, pulp dilution or density, time of contact and aëration. Solutions containing from 0.04 to 0.06 per cent NH_3 were used in the test recorded in the accompanying data. Ammonium hydroxide or ammonia gas may be introduced directly into the pulp or generated *in situ* by decomposition of ammonium salts by alkalies, for example ammonium sulphate and sodium carbonate. The gas is rapidly absorbed or combined with the water forming ammonium hydroxide.

In treating some complex ores containing zinc, copper, lead and iron sulphides, ammonia may be introduced with the frothing agent in the form of an emulsion and good results obtained. With other ores this procedure fails to make a high recovery and it is found necessary to give the ore a preliminary treatment with ammonia and air before introducing the frothing agent.

In the differential flotation of some zinc-copper-iron sulphide ores it was found necessary to substantially remove the ammoniacal solution by decantation and replace with water before adding the frothing agent, otherwise copper sulphide would float with the zinc sulphide. Copper thus floated showed a marked tendency to drop as the ammonia was eliminated in cleaning and recleaning the concentrate and to appear in the middlings.

Neutral Wood Oils Best for Ammonia Process

When ammonia is introduced into ore pulp in conjunction with certain oils, no differential action is manifested and all sulphides are floated. This is particularly true with coal-tar distillates. The most suitable oils for differential flotation are found among the wood products, especially neutral pine oils and neutralized wood creosotes.

As the oxide film or coating on the iron sulphides is only superficial, the best results are obtained in flotation cells giving a maximum amount of aëration and minimum scouring action. This is characteristic of the Callow pneumatic cell. Of mechanical types, the K. & K.

machine is considered efficient. There is evidence but not conclusive proof that an iron machine gives better results than cells which are constructed of other metals or of wood.

A vast amount of valuable information has been acquired relative to differential flotation of metalliferous sulphides, as a result of research for a period of over two years, that can not consistently be given publicity at this time.

Although the accompanying data give some results of tests on zinc-iron sulphide ores, the process is applicable to differential flotation of other metalliferous sulphides, such as molybdenite and graphite, from iron sulphides.

Sources of Ammonia

Ammonia is derived from gas liquor byproduct in the manufacture of coal gas, ammonium sulphate or other salts by decomposition with alkalies. Ammonia is also produced from calcium cyanamide or aluminium nitride by decomposition with superheated steam or by direct union of its elements under pressure (17 atmospheres), heat and a catalyzing agent as in the Haber process.

Aluminium nitride is manufactured from aluminium carbide, a byproduct in the electric smelting of aluminium ore (bauxite), and nitrogen from producer gases, or fractionated liquefied air. Calcium cyanamide is obtained by treating calcium carbide produced by fusion of carbon (powdered coal) and lime in an electric smelting furnace, with nitrogen gas as in the manufacture of aluminium nitride.

Ammonia liquor byproduct from coal-gas usually contains approximately 12 per cent NH_3 and has a market value of about ten cents per pound of ammonia content. The success of the Terry differential flotation process, like all others requiring additional agents, largely depends on the cost of such materials. Synthetic nitrogen products are now manufactured in large quantities, and afford a fairly cheap and abundant supply of this reagent.

New Corrugated Concrete Roofing

Since the success of the asbestos-cement shingle has become well established, it is natural to expect larger fabricated parts to appear, which will occupy a place similar to corrugated iron. The British are now marketing this product. Their method of manufacture is reported to be as follows: Finely ground and cleaned asbestos fibre is mixed with portland cement in the proportion of about 1 to 6, and water enough added to make a dough. The material can be colored red with ochre etc. during mixing. The batter then flows on to a Fourdrinier machine of special design and a sheet formed on a felt.

Special waterproofing dopes are added similar to sizing in the paper industry and the sheets are then trimmed to size and corrugated. Special precautions have to be taken to see that the material does not squeeze thin at the tops of the corrugations, so that the product will be homogeneous as well as proof against breakage at weak spots. The sheets go from the machine to the seasoning shed, where the cement takes its initial set and cures without being disturbed. The pitch of the corrugations is made on the 3-inch basis similar to English corrugated iron, so that the product is flatter than the 2½-inch U. S. pitch.

Corrugated cement-asbestos sheets will be heavier than the metal ones but will be sufficiently durable for mechanical ware and will have the advantage of being far more resistant to atmospheric conditions, especially in chemical plants where acid fumes are present. It is to be hoped that a suitable synthetic siliceous fiber will be developed to take the place of the asbestos.

RESULTS OBTAINED BY THE TERRY DIFFERENTIAL FLOTATION PROCESS

	Percentage Analysis of Ores and Products							Percentage of Total Metals, Etc., in Various Products					
Sample No. 1 Ore — 100 mesh:	Wt.	Zn	Pb	Fe	Cu	CaO	SiO_2	Zn	Pb	Fe	Cu	CaO	SiO_2
Concentrates	21.6	49.20	nil	11.71	0.85	1.10	1.15	85.30	nil	18.00	93.95	3.28	1.03
Middlings	15.2	10.10	.....	12.92	0.05	11.20	24.18	12.29	.....	13.97	7.05	23.51	11.33
Tailings	63.2	0.47	.....	15.15	nil	8.40	44.90	2.41	.....	68.03	00.00	73.21	87.64
Heads	100.0	12.44	.....	14.05	0.20	7.23	32.37	100.00	.....	100.00	100.00	100.00	100.00
Sample No. 2 ore—100 mesh:													
Concentrates	45.2	50.20	nil	12.63	tr.	0.33	1.52	91.71	.....	21.20	.....	39.41	10.44
Middlings	11.6	12.00	.....	34.31	.....	0.75	8.00	5.61	.....	14.78	.....	23.01	14.10
Tailings	43.2	1.55	.....	39.85	.....	0.33	11.50	2.68	.....	64.02	.....	37.58	75.46
Heads	100.0	23.70	.....	25.94	.....	0.48	6.70	100.00	.....	100.00	.....	100.00	100.00
Sample No. 3 ore—100 mesh:													
Concentrates	55.2	49.80	.....	11.98	nil	0.40	0.41	96.08	.....	26.17	.....	45.00	15.60
Middlings added to tailings:													
Tailings	44.8	2.27	.....	41.65	.....	0.62	2.76	3.92	.....	73.83	.....	55.00	84.40
Heads	100.0	28.61	.....	25.26	.....	0.49	1.45	100.00	.....	100.00	.....	100.00	100.00
Sample No. 4 ore—100 mesh:													
Concentrates	30.0	5.50	2.80	14.64	.....	0.60	1.05	61.58	68.89	16.71	.....	13.33	4.00
Middlings	27.6	24.00	0.93	24.60	.....	.....	.....	29.86	20.87	25.86	.....	.....	.....
Tailings	42.4	4.50	0.33	35.60	.....	.....	.....	8.56	10.24	57.43	.....	.....	.....
Heads	100.0	22.17	1.23	26.27	.....	1.35	7.78	100.00	100.00	100.00	.....	.....	.....
Sample No. 5 Table Middlings—100 mesh:													
Concentrates	51.3	48.38	4.10	7.40	.....	.....	1.30	92.5	53.1	7.9	.....	.....	6.40
Tailings (including middlings)	48.7	4.08	3.80	38.60	.....	.....	19.30	7.5	46.9	82.1	.....	.....	93.60
Heads	100.0	26.80	3.95	22.28	.....	.....	10.30	100.0	100.0	100.0	.....	.....	100.00
Sample No. 6 Table Middlings—100 mesh:													
Concentrates	36.0	53.20	3.85	5.08	.....	0.45	2.34	77.44	53.30	13.35	.....	9.70	3.96
Middlings	19.3	23.60	3.52	19.18	.....	1.55	13.26	18.41	26.12	23.35	.....	17.90	12.17
Tailings	44.7	2.30	1.21	22.45	.....	2.70	39.44	4.15	20.58	63.30	.....	72.40	83.87
Heads	100.0	24.73	2.60	15.85	.....	1.67	21.02	100.00	100.00	100.00	.....	100.00	100.00
Sample No. 7 Mill Tailings—80 mesh:													
Concentrates	5.40	60.20	.....	2.25	.....	1.20	.....	72.38	.....	2.00	.....	0.29	.....
Middlings	13.47	7.40	.....	.....	.....	.....	.....	22.04	.....	.....	.....	.....	.....
Tailings	81.13	0.32	.....	.....	.....	.....	.....	5.58	.....	.....	.....	.....	.....
Heads	100.00	4.40	.....	6.06	.....	21.96	7.48	100.00	.....	.....	.....	.....	.....
Sample No. 8 Table Middlings—80 mesh:													
Concentrates	33.60	50.00	5.06	6.72	.....	0.67	1.61	86.91	40.66	.....	.....	.....	.....
Middlings	13.60	15.60	.....	.....	.....	.....	.....	10.96	22.22	.....	.....	.....	.....
Tailings	52.80	0.87	2.86	40.56	.....	.....	.....	2.13	36.12	.....	.....	.....	.....
Heads	100.00	19.33	4.18	27.12	.....	0.92	5.00	100.00	100.00	.....	.....	.....	.....

Imports of gold during the fiscal year 1918 amounted to only $124,000,000 as compared with $977,000,000 in 1917 while exports were valued at $191,000,000 compared with $292,000,000 in 1917. Silver imports amounted to $70,000,000 in 1918 against $35,000,000 in 1917, and silver exports, $1,399,000.

The Present Status of Electric Brass Melting*

A Survey of the Application of Electric Furnaces to the Melting of Brass and Other Copper Alloys—Advantages and Disadvantages of Different Types—Central Station Viewpoint

By H. M. ST. JOHN

ELECTRIC brass-melting has for some time past been the subject of much technical discussion, presented from various points of view. The advantages of the process have been outlined and the progress made with different furnace types have been dealt with in detail by men well qualified to speak with authority. The writer has no desire to duplicate what has already been done so thoroughly. It seems possible, however, that certain fundamental principles, upon which the success of electric melting directly depends, have hardly received, at least in public, the consideration which they deserve. It is the purpose of this paper to discuss these fundamentals, with particular attention to the bearing which they have upon electric-furnace design, and to trace the development of the various furnace types proposed for electric brass-melting, which have succeeded or failed, dependent upon the degree to which these basic principles have been recognized and followed. Finally, it is desired to emphasize the financial interest which the central station industry has in the ultimate success of the electric brass-furnace, and the importance of the part which this industry can take in directing the development of electric melting along sane and rational lines.

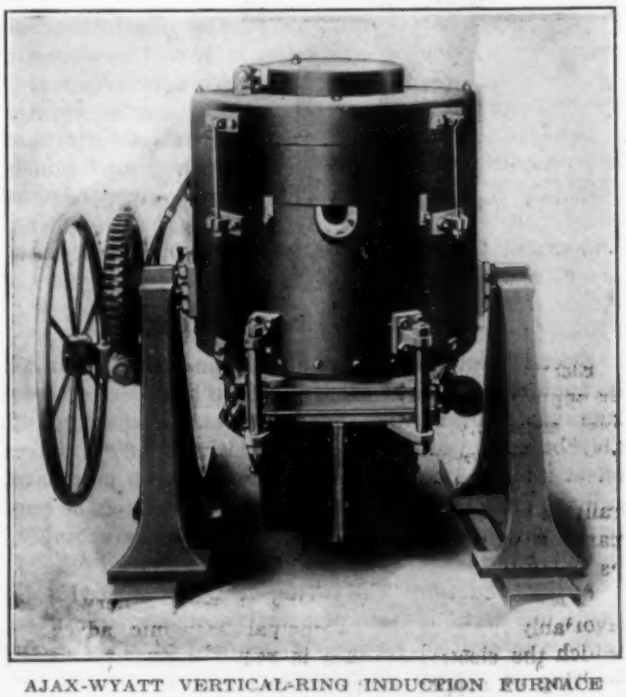
The Field of Electric Brass Melting

In 1914 it was estimated by Gillett[1] that there were, in the United States, at least 3600 plants engaged to some extent in melting brass and bronze. It was further estimated that the value of the metal annually melted by these plants was in the neighborhood of $120,000,000, and that, of this total, the value of the metal lost beyond recovery during the melting operation was not less than $3,000,000.

When one considers the extensive use of brass and bronze in warfare, and the enormous industrial expansion along metallurgical lines which has taken place in this country since 1914, it becomes evident that an estimate made on the basis of present conditions would name figures much larger than those stated in 1914. Even if the total tons of metal melted annually were no greater now than then, the increase in market value of the metals concerned would of itself nearly double the value of the metal produced. An avoidable waste of metal which was then considered important has ever since deserved and received, in constantly increasing degree, the attention of our metallurgists.

It has long been known that it is theoretically possible to eliminate much of this loss by the use of electric melting, particularly in the case of yellow brass and other alloys high in zinc. Most of the electric-furnace development in the copper-alloy field has been carried out with this end in view. Metallurgically speaking, the problem is not a simple one and progress has been rather slow. Important advances have, however, been made since 1914, and the present outlook warrants a considerable degree of optimism.

Two widely different types of electric furnace are now on the market and in commercial use for melting yellow brass, one highly efficient but limited in its use to a portion of the field only, the other less efficient but otherwise more widely applicable. At least one other type of furnace has been experimentally successful and is reported as about to enter the commercial field. Two or three additional types are being actively developed and give some promise of eventual success. So far as yellow brass is concerned, it cannot be said that an entirely satisfactory furnace has yet been produced, but the field has been partially covered, and the prospects for further advancement in the art are good.



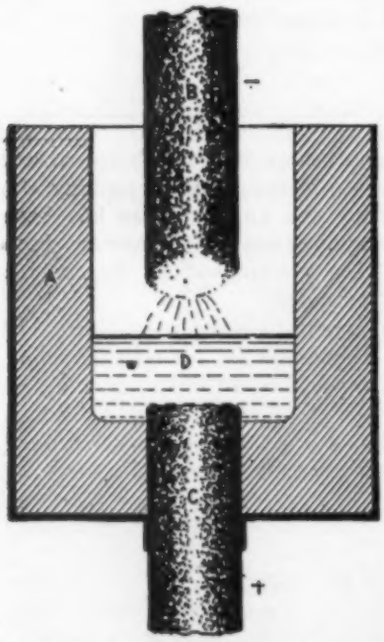
AJAX-WYATT VERTICAL-RING INDUCTION FURNACE

Previous to the war the use of electric furnaces for melting copper alloys did not seem feasible except in cases where a large metal saving helped to counterbalance the higher cost of electric heat. Under present conditions the high cost and poor quality of crucibles, the high cost and shortage of important metals, the high cost and scarcity of labor, and the insistent demand for a high rate of production at any cost, are factors which combine to make electric melting profitable in

*Read before the Ohio Electric Light Association.

[1] H. W. Gillett: "Brass-furnace Practice in the United States." Bureau of Mines *Bulletin* No. 73, page 9 (1914).

many cases where it would previously have been unprofitable. Whether electric-furnace installations which owe their existence to these peculiar conditions will continue to show a profit when normal conditions once more prevail, is still an open question. No one can say when conditions will again become normal, or, for that matter, what sort of conditions will be considered normal in the future. Much will depend upon the progress made in furnace design, and in operating methods, during the continued existence of the economic conditions which at present make possible the electric melting of copper alloys containing little or no zinc. The necessary progress can only be made by the combined efforts of such individuals and companies as are now profiting, and expect to profit in the future, from the increased use of electric furnaces.



DIRECT-HEATING ARC FURNACE
From Stansfield, "The Electric Furnace"
Courtesy The McGraw-Hill Book Co.

Advantages of Electric Melting

Electric heat is expansive at best, and, although it can be applied much more efficiently than heat derived from fuel, especially at high temperatures, it cannot profitably be employed except in cases where its use makes offset its added cost. The advantages which may naturally be expected to accrue from electric melting, as compared with melting in fuel-fired furnaces, are roughly as follows:

1. *Metal Saving.* The saving of metal, otherwise unavoidably lost, is the principal economic advantage which the electric furnace is required to show in the melting of copper alloys, particularly in melting yellow brass. It has been completely demonstrated that such a saving can be made in the electric furnace, by virtue of the fact that the furnace chamber can be tightly closed during the melting period, and a neutral or reducing atmosphere maintained. As we shall see later on, it does not follow that every electric furnace is capable of a favorable performance in this respect. Conditions resulting from the war have greatly accentuated certain other advantages of electric furnace operation, but in more normal times no electric furnace can hope to succeed in this field unless its use results in a saving of metal as compared with fuel-fired practice.

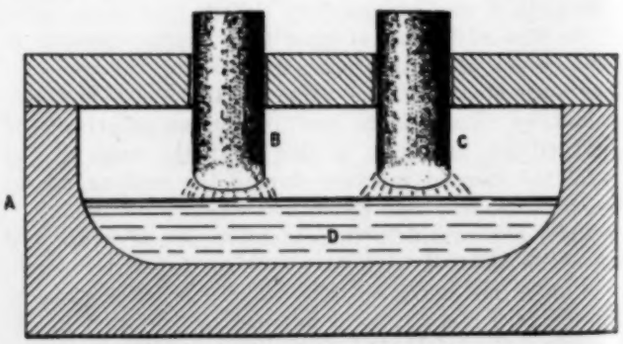
2. *Improved Quality.* It has been found, in most cases, that a more uniform quality of metal can be produced in the electric furnace than in fuel-fired furnaces operating under similar conditions, and that it is easier to produce an alloy of closely specified composition. In general, these advantages can be accepted as inherent in properly conducted electric furnace operation, resulting from the greatly reduced loss of volatile metals and from the elimination of contaminating combustion gases. So far as copper alloys are concerned, it is still undecided whether or not a higher quality of metal can be produced in the electric furnace, as compared with the best of fuel-fired practice. It is beyond question that high quality can be achieved more easily and certainly. The successful electric furnace must be at least as satisfactory in these respects as the best fuel-fired furnace.

3. *Exact Temperature Control.* The production of perfect castings with the least possible number of defectives depends in large degree upon the use of metal at a temperature which conforms closely with that known to be most favorable for the work in hand. The electric furnace lends itself readily to exact temperature control and thereby enjoys an important advantage.

4. *Increased Production.* In general, the speed of melting is greater in electric furnaces than in fuel-fired furnaces, because of their higher operating temperature and greater efficiency. The electric furnace can also be used in larger units than is commonly the case with fuel-fired furnaces.

5. *Elimination of Crucible Cost.* The cost of crucibles is a considerable item even in normal times. Under present conditions this cost is very high. Electric furnaces which use no crucibles eliminate this expense. Large fuel-fired furnaces effect the same saving but, from a metallurgical point of view, are seldom as satisfactory as fuel-fired crucible furnaces. Electric crucible-furnaces deserve little consideration at the present time.

6. *Incidental Savings.* The operation of large units results in an economy of floor space and of labor, dependent upon the use of large electric furnaces where large fuel-fired furnaces are not practicable. Increased production results in decreased overhead and interest charges per ton of metal turned out.



DIRECT HEATING SERIES-ARC FURNACE
From Stansfield, "The Electric Furnace"
Courtesy The McGraw-Hill Book Co.

7. *Better Working Conditions.* More favorable conditions for the workmen, tending to increase their efficiency as well as their comfort, result when excessive heat, noise, and fumes are eliminated. The properly selected and correctly operated electric furnace is almost ideal in this respect. In installations where the reverse is true, the trouble is due to the use of an unsuitable furnace, or to careless operation, or to both of these as contributing causes.

It should not be understood that these advantages necessarily follow from the use of any electric furnace which may happen to be selected. The furnace must be of suitable type, properly designed and correctly used. A misapplied electric furnace may prove worse in almost every respect than the fuel-fired furnace which it replaces.

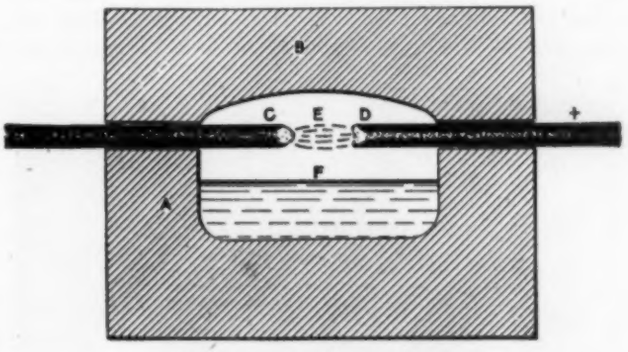
Requirements of Electric Melting

First consideration must always be given to metallurgical requirements. No electric furnace can achieve success unless it performs satisfactorily the function which is expected of it, no matter how efficient it may be nor how admirable its design may appear in other respects. Unless the design is metallurgically correct, the furnace is useless as an industrial tool.

Steel may be classed as a peculiarly "stolid" metal; it melts at a high temperature, and it may be heated as rapidly as you please during the melting operation, providing it is not exposed to contaminating elements during the process. With copper alloys the case is quite otherwise. Copper itself is somewhat volatile and oxidizes much more readily than steel, when in the molten state. Lead is somewhat volatile—more so than copper—and oxidizes very easily. Zinc is exceedingly volatile at molten-brass temperatures. All copper alloys must be treated carefully during the melting process in order that losses of metal by oxidation and volatilization may be kept at a minimum.

Yellow brass for thin castings must be poured at a temperature not far below its boiling point in order that the metal may be sufficiently fluid. At this temperature, zinc, which comprises 30 to 35 per cent of the alloy, has a tendency to vaporize rapidly. So long as the metal is contained in a tightly closed furnace chamber, which can easily be done in the electric furnace, this tendency is counter-balanced by the vapor pressure of the metal which has already been vaporized and with which the furnace atmosphere is saturated. When the furnace is opened for pouring the metal, or for any other purpose, the vapor pressure is released and further quantities of zinc will escape from the metal without restraint. If the heating has been perfectly uniform and all portions of the melt are at approximately the same temperature, the loss of zinc which ensues will constitute an unavoidable minimum. If the heating has not been uniform, some portions of the melt will be at a temperature higher than the desired pouring temperature, and such portions will lose zinc at a higher rate. If the lack of temperature uniformity is very great the loss which occurs after the furnace is opened, and during pouring, will be decidedly excessive. In fact, some portions of the metal may be so seriously overheated during melting that the high vapor pressure formed within the furnace will force considerable quantities of zinc vapor through crevices in the furnace structure. In some cases it may be practically impossible to keep the furnace chamber closed, even to a reasonable degree. Under such conditions the zinc losses are likely to be quite as serious as in fuel-fired crucible furnaces, or even more so.

What is true of yellow brass poured at a temperature near its boiling point is also true, although in less degree, of yellow brass poured at lower temperatures, and of other copper alloys. The lower the percentage of volatile metal the more easily the alloy will stand up under uneven heating. But it can be accepted as an axiom of copper-alloy melting that heat must be applied to the metal as uniformly as possible, whether the alloy under treatment is a brass, a bronze, or some one of the less common alloys. If the application of heat in the furnace lacks uniformity to a serious degree, an excessive loss can only be prevented by some method of stirring



INDIRECT ARC FURNACE
From Stansfield, "The Electric Furnace"
Courtesy The McGraw-Hill Book Co.

the metal, and this stirring must be effected within the furnace, without opening the furnace doors.

The metal as poured from the furnace must be uniform in composition, with its various constituent metals thoroughly well mixed and alloyed. In some cases a rigidly specified composition must be closely met. The finished casting or ingot must be of a quality at least as good, with respect to strength, freedom from cracks, blowholes, etc., as that obtainable from fuel-fired crucible furnaces.

Since electric heat is more costly than that derived directly from fuel, it is important that the thermal efficiency of the electric furnace should be as high as can be obtained consistent with other requirements. A high thermal efficiency in electric melting, unless heat is generated in the metal itself, requires a high-temperature heat source, located as close as may be to the metal, under conditions which offer the least possible opposition to the flow of heat from the source to the metal. At the same time the walls of the furnace must be sufficiently thick and of high heat-insulating quality in order that heat may not be dissipated uselessly from the outer walls.

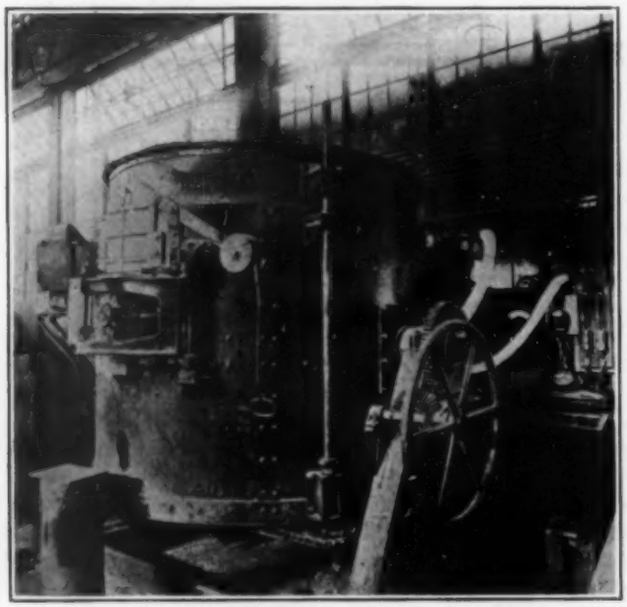
In some furnace types these requirements are directly opposed to the metallurgical requirements already considered. In such cases thermal efficiency must be sacrificed to as great a degree as may be necessary in order to satisfy the metallurgical requirements. The highest efficiency consistent with good metallurgical results should be maintained; any higher efficiency is false economy. Of course, other things being equal, the more efficient type of furnace will meet with greater success.

The electric furnace, to reap the full benefit of its economic possibilities, must operate in large units and must not use crucibles. The higher its speed of melting the better, so long as speed is not detrimental to metallurgical results.

The electrical characteristics of the furnace must be such as to make it a desirable load for the central station company or the factory power plant. Its power factor must not be abnormally low and its power fluctu-

ations must not be so violent as to endanger transformers and other electrical equipment, or to interfere with satisfactory service to other customers of the central station company who may be connected to the same power line.

It seems hardly necessary to add that the successful electric furnace must be sturdy and reliable, quite as capable of performing its function, day in and day out, under regular operating conditions, as are the best types of fuel-fired furnaces. The furnace and its adjustments should be as simple as possible, although with



BAILEY INDIRECT RESISTANCE FURNACE

a large electric furnace it is permissible, and nearly always desirable, to use a higher grade of operator than would be employed to tend fuel-fired crucible furnaces.

Furnace Development

A great variety of electric furnace types have been proposed and tried out for melting brass. It is hardly an exaggeration to say that every known method of applying electric heat to a metal has been utilized by one or another of the various designs which have reached at least an advanced experimental stage. Some of these types have been eliminated as inherently unsuited for the purpose; some have been abandoned because of difficulties which may eventually be overcome by other investigators; others, partially successful, have apparently reached the height of their development; still others seem to possess greater possibilities of ultimate success than have yet been demonstrated.

Direct-Resistance and Induction Furnaces

The most obvious method of reaching a high thermal efficiency without overheating the alloy is to generate heat in the metal itself by the passage of an electric current through it. This may be done either by means of a direct-resistance furnace, in which electrical contact with the metal is made through electrodes, or by means of an induction furnace, in which case the metal forms a complete circuit for the flow of an induced electric current, without the use of electrodes. In either case it is practically necessary to establish the circuit through molten metal, previously melted in some other furnace.

The "pinch-effect" direct-resistance furnace was the first to utilize this principle. In this type the circuit consists of two or more vertical or inclined resistor channels in the hearth of the furnace, terminated at the lower end by electrodes, and opening at the upper end into the main portion of the metal bath, which conducts the current from one resistor channel to another. The resistor channels are so designed as to length and cross-section that the pinch phenomenon occurs in them continuously during operation. The resultant effect is a constant stream of hot metal issuing from the resistor channels, with considerable force, into the metal bath above, while colder metal flows down to take its place and is heated and ejected in its turn. Virtually all of the heat is generated in the molten metal temporarily designed for steel melting have been tried, but no new type of direct-arc furnace has been developed for this specific purpose. No furnace of this general type has ever succeeded in satisfactorily melting yellow brass, or other copper alloys containing an appreciable percentage of zinc. The high-temperature heat source in direct contact with the bath overheats the metal in its immediate vicinity and invariably causes an excessive loss of zinc.

With copper alloys containing no zinc the case is somewhat different, since lack of uniformity in heating is less likely to result in serious loss. In a direct-arc furnace of small size it has been found possible to melt a copper alloy containing as much as 15 to 20 per cent lead at a loss less than that commonly experienced with the same alloy in fuel-fired crucible furnaces. In larger furnaces the greatly increased rate of heat input supplies heat to the metal, in the neighborhood of the arc, more rapidly than it can be conducted away to more distant portions; the surface of the metal becomes overheated while other parts of the bath are still much below the desired temperature.

The direct-arc furnace has the advantage of simplicity and high thermal efficiency; its design has been more highly developed and perfected than that of most other electric furnace types and, since it is so widely used in the steel industry, several furnace designs are on the market, reliable and readily available. It is very doubtful, however, if any direct-arc furnace deserves wide application for melting copper alloys. Its use is limited to only a few of the common alloys, and, if large units are employed, the metal loss, even with these alloys, is likely to be serious. Small units are more satisfactory in this respect but are subject to the disadvantages of lower efficiency, higher fixed charges, and higher operating costs per ton of metal produced.

Such direct-arc furnaces as are now in use in this field—and there are a few—hold their place by virtue of their simplicity, elimination of crucible cost, and their high rate of production, at a time when these qualities are at a premium.

Indirect-Arc Furnaces

The intensity of heat application to the metal is lessened somewhat by using an arc between two or more independent electrodes above the bath, heating the latter by direct radiation. This is the principle of the usual type of indirect-arc furnace. The arc does not come in

direct contact with the metal and the latter forms no part of the electric circuit. It is apparent that in this type of furnace the surface of the metal is not so seriously overheated as in the direct-arc furnace, but such overheating as exists is, nevertheless, too severe to permit the use of such furnaces in melting yellow brass. The indirect-arc furnace can be used economically with alloys containing 5 to 10 per cent of zinc, possibly as high as 20 per cent, but certainly not for higher values.

The design of the indirect-arc furnace is invariably somewhat more complicated than is the case with the direct-arc furnace, and its thermal efficiency is not so high, but, in the melting of copper alloys, it can be economically used in larger units, and seems to be, in general, a more satisfactory tool for the purpose.

Several indirect-arc furnaces are now in use in this country for melting copper alloys which contain small percentages of zinc or none at all.

In a new type of indirect-arc furnace,[2] the metal, as soon as it becomes molten, is agitated by rocking the furnace mechanically, in order to avoid overheating of the surface layer. In this way non-uniformity of heating is largely rectified, and it is possible that alloys high in zinc can be melted without excessive loss. The furnace has received a comprehensive commercial test, and, according to report, will soon be placed on the market. This type gives considerable promise of success and should be applicable to a wide field of alloy melting.

Indirect-Resistance Furnaces

Resistance furnaces which do not utilize the metal itself as an electric resistor may be grouped in three classes: (1) Those which radiate heat directly to the metal, similar in principle to the indirect-arc furnace, (2) those which radiate heat to the furnace roof and thence to the metal by reflection and secondary radiation, (3) those which feed heat to the metal by conduction through a refractory wall.

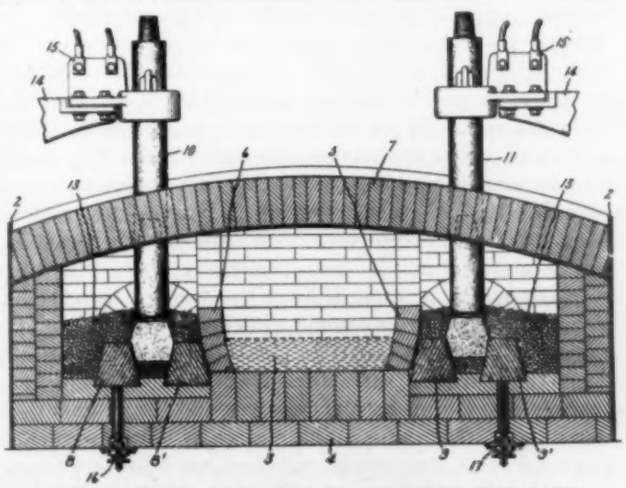
Heating by direct radiation is the most desirable of the three from the standpoint of efficiency. For this purpose it is practically necessary to support the resistor above the bath in some manner, and this has never been done successfully in furnaces of any considerable size. In small furnaces it has been possible to utilize this principle and to melt brass satisfactorily without overheating the surface of the metal to an undesirable degree, since, as compared with an arc, the resistor has a large area and operates at a much lower temperature. At the same melting speed the application of heat to the metal is more uniform but the efficiency is somewhat less.

This type of furnace is applicable to yellow brass but is not in commercial use because of the mechanical difficulties involved in its construction. The possibility of its eventual use depends upon the development of a resistor material which is at once highly refractory, homogeneous, mechanically strong at high temperatures, and possessed of a fairly high electrical resistance at the working temperature of the furnace.

The second type named ranks next in the order of thermal-efficiency. In this design a refractory wall separates the resistor from the metal—although not necessarily in contact with the metal—and the major portion of the heat is radiated from the resistor to the furnace roof, the latter acting as a secondary heat source which reflects and radiates part of the heat which it receives to the bath beneath it. The heat has to travel rather a long path and much of it is lost by the wayside. As a result, the furnace is not so efficient in principle as those previously discussed. In order to stimulate a reasonably rapid flow of heat the resistor element must be much hotter than the roof, and the roof, in turn, much hotter than the metal. Thus the possibility of a high rate of production depends upon the use of a resistor capable of operating at a temperature very much above that of the metal, even at the pouring point. The furnace roof must be exceedingly refractory and the brickwork in the immediate neighborhood of the resistor must be even more refractory than the roof. In the present state of the art these conditions are difficult to meet, and the production speed of this type of furnace is consequently somewhat limited.

The furnace, in common with other indirect resistance furnaces, contends with another disadvantage, somewhat minor in character but worth considering, which is not found in direct-resistance furnaces nor, to any great degree, in arc furnaces. The heat storage of the furnace is large and the stored heat is at a temperature higher than that of the metal. As a consequence, the temperature of the metal will continue to increase after power has been shut off. When the metal has reached its desired pouring temperature it must be poured promptly in order to avoid overheating. It is often impossible to hold the molten charge in the furnace, even for a few minutes, without serious metal loss.

This is the only form of indirect-resistance furnace which has found commercial use for melting copper alloys. In its present form, it is simple, reliable, easy to operate, and can be used on practically any alloy, for either intermittent or continuous operation. Its metallurgical characteristics are excellent, with the single exception that it is somewhat difficult to secure thorough mixing, and it is especially suitable for melting alloys high in zinc. Its production rate is not rapid and it is not so efficient as the furnace types already described.



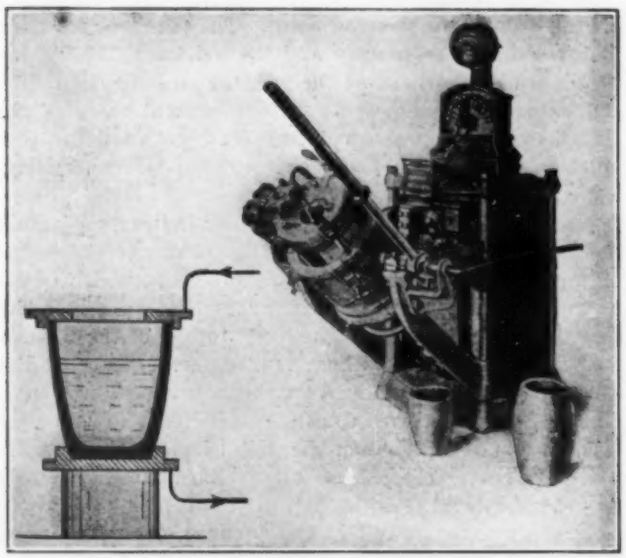
COMBINATION ARC AND RESISTANCE FURNACE

A similar type of furnace utilizes a combination of arcs and resistance elements, all radiating heat to the furnace roof, which, as in the furnace just described, serves as a secondary heat source. The use of arcs makes possible a considerably higher power input, more rapid

[2] H. W. Gillett and A. E. Rhoads: "A Rocking Electric Brass Furnace," *Met. & Chem.* Vol. XVIII, No. 11 (1918), page 583.

melting, and probably a slightly more favorable efficiency, provided a sufficiently refractory roof is used. A very high efficiency cannot, however, be expected from this type of furnace. Certain difficulties in furnace design have been encountered which have so far postponed the commercial use of this furnace. It has been under test for some time, but the results obtained have not yet been made public.

The least efficient method of transferring heat from its source to the metal is to force it through a refrac-



HELBERGER RESISTANCE FURNACE
From Rodenhauser's "Electric Furnaces"
Courtesy of John Wiley & Sons

tory wall, even though this wall be that of a clay-graphite crucible, a mixture which has a fairly high heat conductivity. Theoretically, the least undesirable arrangement under these conditions is to enclose the resistor in the refractory wall or to use the wall itself as a resister. In the latter case the wall must be separated from the metal by an insulating layer to prevent short circuiting. It is not an easy matter to make this insulation permanent and this factor has been a serious source of difficulty. A resistor enclosed in a refractory wall tends to reach excessively high internal temperatures, and no material has yet been found, satisfactory in other respects, which will not destroy itself under these conditions. Another troublesome difficulty results from the ease with which most resistor materials unite chemically with the furnace refractories at high temperatures, thereby destroying both themselves and the refractories. Some two or three furnace types have been designed to make use of this principle, but they have been uniformly unsuccessful. There is at present no real activity along this line.

Electric Crucible-Furnace Inefficient

Finally, it is possible to melt brass in a crucible by means of resistor elements which surround but do not touch the crucible. Perhaps the most perfect results, from a metallurgical standpoint, can be obtained in this manner, but thermal efficiency is at a minimum and, in any case, the electric crucible-furnace lacks most of the secondary advantages upon which the electric brass-melting furnace must depend in part for its successful use. It is possible that, in cases where perfection of metallurgical results is by far the most important consideration, an electric crucible-furnace can profitably be employed, but, so far as known to the writer, no commercial installation of this kind exists.

So far as thermal efficiency is concerned, the crucible furnace takes its place at the bottom of the list. Its energy consumption per ton of metal produced is about three times that of the induction furnace. One or two attempts have been made to improve the efficiency by constructing a multiple-crucible furnace, with resistor elements suitably arranged between crucibles. In this way it is possible to make a substantial gain in efficiency, but there are serious objections to this type of construction and its development has been dropped.

Present Status of Electric Melting

We find, then, that there are four types of electric furnace in commercial use for melting copper alloys. Of these, only two are suitable for use with alloys high in zinc. One, the vertical-ring induction furnace, is of high efficiency, but somewhat limited as to its application and not sufficiently flexible for general foundry use. Within its limited range it appears to be giving very satisfactory results. The indirect-resistance, indirect-radiation furnace is less efficient and has a lower rate of production in proportion to its holding capacity, but is more flexible and better suited to general foundry use. Neither of these furnaces can be classed as altogether satisfactory but each is serving a useful purpose.

The indirect-arc furnace is in use for melting alloys which contain small percentages of zinc and those which contain no zinc at all. It is more efficient than the indirect-resistance furnace and, within its field, more flexible than the induction furnace.

The direct-arc furnace is being used, to a limited extent, in melting copper alloys which contain no zinc. Present conditions make its use profitable in some cases, but its continued application for this purpose is not assured.

The most promising possibilities, not yet in commercial use, are, first, a form of induction furnace which will be, not only efficient, but also flexible and capable of widespread application, and, second, a form of arc furnace which will be applicable to yellow brass and other high-zinc alloys, as well as to the less sensitive alloys. Able efforts are being made to reach both of these goals. There may be some hope, eventually, of an indirect-resistance, direct-radiation furnace which will be commercially useful, but at present no steps are being taken to perfect such a type.

Electric crucible-furnaces, which are at once reliable and effective, can be built and, in fact, have found some commercial use for melting precious and semi-precious metals. In the field of copper alloys, there seems little prospect that their use will ever be profitable except, perhaps, to a limited extent, under out-of-the-ordinary conditions.

The Central Station Viewpoint

If all the brass and bronze produced in the United States were to be melted in electric furnaces the annual consumption of electric energy for this purpose would be in the neighborhood of 200,000,000 kilowatt hours, and the generating capacity required to supply the neces-

sary power would be about 75,000 kilowatts. There is little reason to expect the complete electrification of this industry, either now or in the future, but the expansion in this field which may reasonably be predicted is sufficiently large to be interesting to the central station companies.

The central station not only has an object in promoting the satisfactory progress of this development, but has at stake interests which can only be protected occupying these channels or tubes. The main portion of the metal, occupying the furnace chamber above, is heated by contact with the hot metal, and solid metal added to the bath is melted by the same means.

The stirring action of the moving streams of metal is vigorous and the temperature of the main portion of the bath rises uniformly. There is no difficulty in restraining the vaporization of zinc, and, in fact, it may be said that the metallurgical requirements of any single alloy are almost perfectly fulfilled.

Generation of heat in the metal itself, where its presence is desired, is theoretically ideal from the standpoint of efficiency, since no part of the furnace is any hotter than the metal, and wall losses are reduced to a minimum. In this case, however, another factor tends to reduce the efficiency. The operating voltage of the furnace is necessarily very low and the current correspondingly high. The massive metallic electrodes are excellent conductors of heat and require a considerable degree of water-cooling. In this way a large quantity of heat escapes from the furnace, and the thermal efficiency is much lower than would otherwise be the case.

Considerable difficulty has also been experienced in constructing satisfactory transformers for use with such extremely low voltages and high currents as are required.

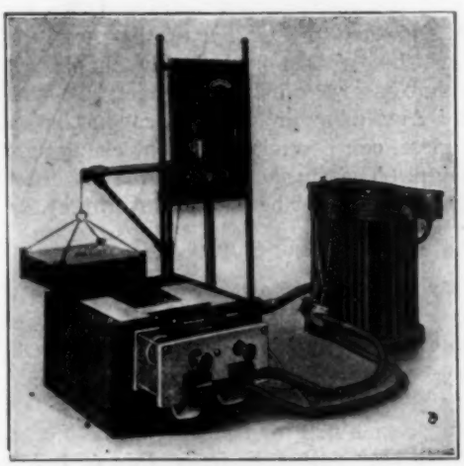
The next step in this development was the application of a similar principle to the induction furnace. This eliminated the use of electrodes and the troublesome transformers, since the furnace now served as its own transformer. In this design the resistor channels meet at their lower end, two of them forming a single V-shaped resistor, opening as before into the metal bath above. The generation of heat takes place as before in the resistor channels, and the same vigorous circulation of metal results. Whether this action is now due primarily to the pinch phenomenon, or to a motor effect resulting from the flow of current through the continuous molten resistor, is open to question. It is difficult to tell where one phenomenon leaves off and the other begins.

The thermal efficiency of this furnace, operating, as it does, without electrodes, is very high, probably higher than that of any other electric furnace ever tried out for copper alloy work. Its metallurgical characteristics are also excellent. It offers a perfectly steady, uniform load at a power factor which is satisfactory, at least in the relatively small sizes so far built, the largest taking a 60-kw. input and pouring 600 lb. of metal per heat. In larger sizes there might be trouble with low power factor, as is so frequently the case with large induction furnaces.

The furnace is in commercial use and is said to be giving satisfactory results. It has, however, pronounced limitations which are partly inherent in its design and partly remediable. Its small size is one disadvantage but it is probable that somewhat larger sizes can be successfully built. It has not so far been found practicable to use the furnace with alloys high in lead, because that metal has a tendency to penetrate minute cracks in the lining of the resistor channels, causing short circuits. The remedy for this awaits the development of a lining especially suited for use with lead.

Limitations of Induction Furnace

The more serious limitations of the furnace are its lack of flexibility in changing from one alloy to another and the practical necessity of operating it continuously, allowing the furnace to cool not oftener than once a week. The length and cross-section of the resistor channels are especially designed to accord with the electrical resistance—in the molten state—of the alloy which is to be used. The same resistor channels cannot be employed with another alloy of widely different resistance, which, accordingly, requires the installation of new channels of properly modified design. In changing from one alloy



HOSKINS CRUCIBLE FURNACE

to another, even if the resistance is approximately the same, it is necessary to pour the furnace clean and start with a molten charge of the new alloy, melted in another furnace.

The linings of the resistor channels stand up very well under continuous use but deteriorate rapidly under the daily heating and cooling of ten-hour day operation. This can be obviated by maintaining over night sufficient power to keep the channels filled with molten metal, which, of course, results in some addition to the cost of operation.

The limitations described tend to prevent the use of this furnace in commercial foundries, which melt a wide variety of alloys and do not work nights, but form no bar to its use in yellow-brass rolling mills, to the purposes of which it seems well suited.

New Design of Induction Furnace

There has been proposed a new design of induction furnace which would not be subject to these limitations. In this type a spark gap and an arrangement of condensers connected in series and in parallel are used in the primary circuit of the furnace, which operates at about 10,000 volts and some 15,000 to 20,000 cycles. The secondary of the furnace consists of a crucible or melting chamber with electrically conducting walls; the

metal within the crucible also carries part of the secondary current, to a minor degree when it is first charged in the form of solid pieces, to a much greater degree when it becomes molten. The primary circuit is arranged around the melting chamber and separated from it by suitable refractory and heat-insulating walls. The furnace is, in a sense, an eddy-current rather than an induction furnace, since no iron cores are used and the metal itself, lying in a circular pool, completely short circuits what, in an induction furnace, would be called the secondary circuit. This unique arrangement is made possible by the exceedingly high frequency used.

At last accounts this furnace had only been built in very small sizes, capable of pouring not more than 45 lb. of metal per heat. It is understood that the furnace is being developed energetically and it is possible that larger sizes have been built during the past six months. The design is so new and unusual that it is difficult to predict the performance of larger sizes, as to efficiency, power factor etc. There is no apparent reason why the metallurgical characteristics should not be good, and the construction of the metal-containing portion of the furnace is desirably simple. It is obviously unnecessary to use molten metal in starting the furnace. Any alloy or even nonconducting material, such as glass, can be melted without changing the furnace design. The furnace is suitable for intermittent operation and need not be kept hot overnight.

Arc Furnaces

Next to the methods already described the most direct way of applying heat to the metal is by means of an outside heat source in direct contact with the bath. The direct-arc furnace is the only type which utilizes this principle.

The application of direct-arc furnaces to copper alloy melting has been rather limited. One or two furnaces by a constant oversight of such features of the development as directly concern itself. For example, all furnaces are not equally satisfactory from the standpoint of economical power supply, and the power company which expects to furnish power for an electric furnace installation should, for its own sake, be familiar with the electrical and operating characteristics of the furnace.

There is an even more vital point to be considered. The central station company sells to its customers a raw material, electric energy. Electric energy must always be converted into some other form of energy by the customer before it is of the slightest use to him. Various devices are used to convert electric energy into heat, light, mechanical energy, or chemical energy. The electric furnace is such a device. These converting devices are customarily purchased, operated, and controlled by the customer. The success of his business depends in part upon their proper selection and correct use. But the success of the central station company also depends upon the proper selection and correct use of the customer's equipment, since the customer's use of the company's service cannot possibly be a satisfactory one if its method of application is faulty. This may be a matter of minor importance insofar as it concerns the use of motors and other well standardized equipment; it is a matter of great importance when it involves new electrical devices or new processes which are not well understood and are, perhaps, entering the industrial world in a somewhat crude and undeveloped form.

Not all electric furnaces are good. Good electric furnaces can be misapplied. Such misapplications have been made and are now being made. Good electric furnaces, properly applied, may result in failure because of faulty operation. This, too, has happened. When such a failure occurs three parties suffer. The user of the furnace has lost some money, but he can go back to his old practice and use a fuel-fired furnace. The seller of the furnace has lost a customer, but he can find another, a few hundred miles away, who has never heard of the failure. The central station company has lost an opportunity to extend a profitable phase of its business. Every such failure becomes town talk, in an industrial sense, in the community in which it has occurred, and makes it increasingly difficult to promote the use of electric furnaces in that locality. The business of the central station company is generally limited to a relatively small territory, and its loss of possible future profits is correspondingly greater, because more concentrated, than that of the seller of electric furnaces.

The central station industry has something to gain by the successful development and use of electric furnaces, it has something to lose by their failure. It is in a position to protect this interest if it cares to do so. The central station company can, by virtue of a little effort, inform itself quite fully concerning the possibilities of electric furnace application within its territory. It can, in a similar way, make itself familiar with such requirements of its customers as have a bearing on electric furnace use. It will then have a wider knowledge than its customers of the electric furnace situation at large; it will have a more detailed knowledge of electric furnace possibilities and requirements within its territory than has the electric furnace salesman. By proper use of this knowledge and of such influence as it ought to possess in the industrial community which it serves, the central station company can promote well advised applications, prevent misapplications, point the way to correct use, discourage incorrect use, and insure the profitable development, within its field of operations, of this newest of electric load builders, the electric furnace.

Commonwealth Edison Co.,
Chicago, Illinois.

Chemists Needed in War Industries

Provision has been made through an order of the Secretary of War dated May 10, 1918, by which manufacturers of material necessary to the prosecution of the war, who have lost the services of chemists through the draft, may again obtain these men for war work.

Provision has also been made whereby manufacturers threatened with the loss of their trained chemists in the present draft may retain these men. Only those chemists, however, whose services are necessary to war work, will be considered and the evidence submitted by the manufacturer must be conclusive.

Manufacturers thus affected should apply to the Industrial Relations Section of the Chemical Warfare Service, U. S. A., Unit F., Seventh and B Streets, Washington, D. C., for the regulations governing men already drafted, or the possible reclassification of men not yet called.

Aluminium and Its Light Alloys—III

The Constitution and Properties of Aluminium Alloys with Copper, Iron, Manganese, Nickel, Silicon and Zinc—Aluminium-Zinc Alloys Lost Tensile Strength with Increase in Temperature

BY PAUL D. MERICA

IX. INVESTIGATION OF ALLOY SERIES

1. ALUMINIUM-COPPER

THE constitution of these alloys has been studied by Gwyer (378), Carpenter and Edwards (381), Curry (382), and Guillet (384, 385). On the aluminium side of the constitution diagram a compound, $CuAl_2$, is formed which is partially soluble in aluminium; the exact solubility has not been determined but is undoubtedly not far from 3 per cent of copper. The eutectic of aluminium and $CuAl_2$ is at 32 per cent copper and 545 deg. C. No thermal transformations have been noticed below the eutectic temperature.

The principal research on this series of alloys is that by Carpenter and Edwards, who in addition to their studies of the constitution of this system contribute results of mechanical and corrosion tests, given below.

The tensile properties of these alloys as sand and chill cast are shown in Figs. 12 and 13. It is noted that the tensile strength of the alloy increases with the increase of copper content. The alloy containing 8 per cent of copper is one very commonly used in the aluminium casting industry to-day. Tests were made upon sand castings to ascertain the effect of heat treatment, consisting of quenching from 450 deg. C. and annealing at 450 deg. C. The alloy containing 8.08 per cent of copper showed, as sand cast, a tensile strength of 16,600 lb. per sq.in. with approximately 2 per cent elongation; as sand cast and annealed a tensile strength of 15,900 lb. per sq.in.; and as sand cast and quenched, 18,000 lb. per sq.in. Quenched alloys were consistently higher in tensile strength than the cast or cast and annealed alloys.

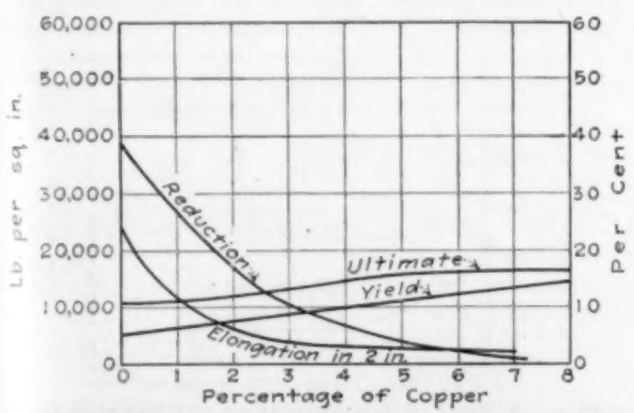


FIG. 12.—TENSILE PROPERTIES OF ALUMINIUM—COPPER SAND CAST ALLOYS (CARPENTER AND EDWARDS)

Ingots 3 in. in diameter and 20 in. long were heated to 400 deg. C. and rolled in round grooves to a diameter of 1¼ in. From this rod portions were hot rolled to $\frac{13}{16}$ in. in diameter and drawn after annealing to $\frac{13}{16}$-in. diameter. From 0 to 8 per cent of copper, all of the alloys rolled well, and from 0 to 4 per cent of copper they could be drawn sound. In Fig. 14 are shown the results of the tests of 1¼-in. diameter hot rolled bars. The bars rolled to $\frac{13}{16}$-in. diameter showed throughout a higher tensile strength than those rolled to 1¼ in., amounting to from 2000 to 3000 lb. per sq.in. The bars drawn with and without annealing showed a higher tensile strength but also a smaller elongation. In Table 8 are shown the test results of an alloy containing 3.76 per cent of copper in different conditions.

TABLE VIII—TENSILE PROPERTIES OF AN ALUMINIUM-COPPER ALLOY

(Carpenter and Edwards, 381)
(Alloy containing 3.76 Per Cent Cu in Different Forms)

	Tensile Strength Lb. Per Sq.In.	Yield Point Lb. Per Sq.In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent
Chill casting	21,500	12,100	10.5	21.46
1¼-in. hot rolled bar	37,700	20,100	20.0	38.21
¾-in. hot rolled bar	38,000	26,000	21.0	49.76
¾-in. bar drawn with annealing	37,900	34,600	8.0	21.79
¾-in. bar cold drawn without annealing	44,900	41,500	7.5	20.84

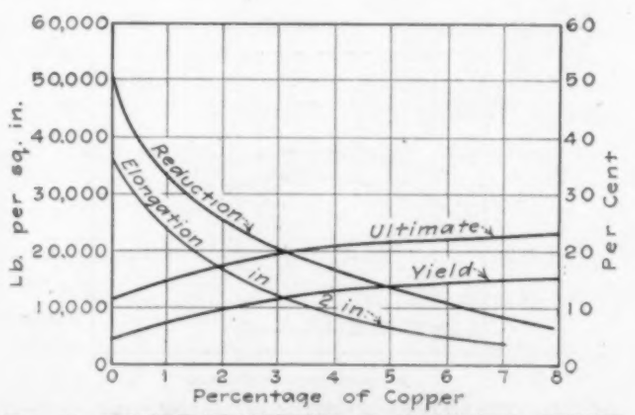


FIG. 13.—TENSILE PROPERTIES OF ALUMINIUM—COPPER CHILL CAST ALLOYS (CARPENTER AND EDWARDS)

Sheets were rolled from an ingot 6½x9¾x⅝ in. by hot rolling at ⅜ in., allowing to cool, and cold rolling to ¼ in. The resulting slab was then cut into portions and the portions rolled down to different thicknesses with intermediate annealing. In Fig. 15 are shown the results of tests upon a sheet rolled to 0.05 in. in thickness. The tensile test results on these sheets are very similar to those obtained on the same alloy in the form of rolled or drawn bars. The authors draw the conclusion that there is nothing to be gained by adding more than 4 per cent of copper for rolling or forging alloy, as well as for a casting alloy. Their conclusion as regards the casting alloy is not in accord with modern practice,

which favors the use of an alloy containing 8 per cent of copper.

Plates cut from rolled sheets of copper contents varying from 0 to 5.34 per cent were exposed for 62 days to the action of both seawater and fresh water. Those exposed to fresh water were slightly corroded but gained in weight due to the coating of aluminium hydrate formed. Those exposed to the action of sea-water were

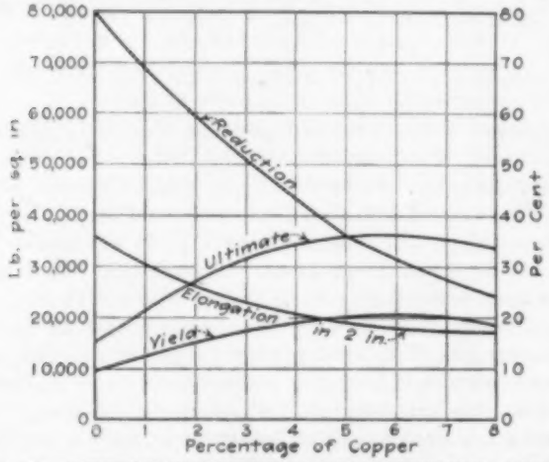


FIG. 14.—TENSILE PROPERTIES OF ALUMINIUM—COPPER ALLOYS; 1¼-IN. HOT ROLLED BARS (CARPENTER AND EDWARDS)

badly corroded and pitted; the losses in weight are given below:

Per Cent Copper	Loss of Weight in Sea-water; Lb. Per Sq.Ft. Per Month
0.00	0.008
0.93	0.008
1.57	0.008
2.36	0.007
3.74	0.005
4.74	0.004
5.34	0.003

The loss of weight is considerable, for the first three

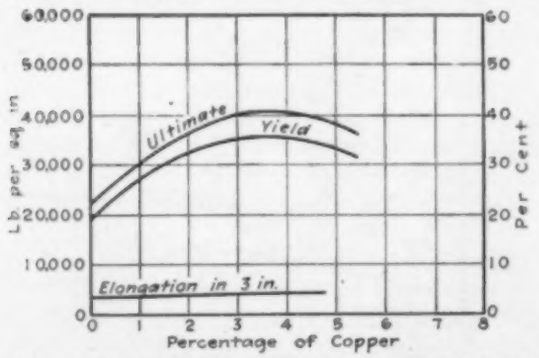


FIG. 15.—TENSILE PROPERTIES OF ALUMINIUM—COPPER ALLOYS; PLATES 0.05 IN. THICK (CARPENTER AND EDWARDS)

alloys, about 3½ times that which would be experienced by mild steel under the same conditions.

It is concluded that these alloys are not suitable for construction which will be exposed to sea-water.

2. ALUMINIUM-IRON

Gwyer (390) has studied the constitution of this system. On the aluminium side a compound, $FeAl_3$, is formed which gives a eutectic with aluminium at practically 0 per cent iron, at 649 deg. C. The compound is not appreciably soluble in aluminium.

Schirmeister below gives the results of some mechanical tests of iron-aluminium alloys.

3. ALUMINIUM-MAGNESIUM

Grube (402) has investigated the constitution of the aluminium-magnesium alloy series and has found that a compound, Al_3Mg_4, is formed, melting at 465 deg. C. This compound forms a eutectic with aluminium at 453 deg. C. and 35 per cent magnesium. The solubility of Al_3Mg_4 in Al has never been determined; it is approximately 10 per cent.

Schirmeister (see below) has investigated the rolling and mechanical properties of this series. Up to 6 per cent magnesium the alloys may be rolled hot and cold; beyond that they are too brittle.

Lane (320) has studied the effect of small amounts of magnesium in dioxidizing and hardening sand cast 99 per cent aluminium. Averages of his results are plotted in figure 16. It is interesting to note that the effect of the magnesium makes itself evident in stages.

Alloys of this series are lighter than aluminium and have attracted on that account much interest from those seeking strong light alloys. Under the name of magnalium, alloys of this series are used for casting purposes, and are described below. This series has never become commercially important for rolling alloys. Alloys having 30 per cent and more of magnesium take a high polish and are used for mirror metal.

4. ALUMINIUM-MANGANESE AND ALUMINIUM-MANGANESE-COPPER

This binary system has been studied by Hindrichs (405). A compound, $MnAl_6$ (?) is formed, giving a eutectic with aluminium at 3 to 4 per cent manganese and 650 deg. C. It is insoluble in aluminium.

Schirmeister (see below) has contributed results of tests of light manganese-aluminium alloys.

Rosenhain and Lantsberry (466) have carried out some tests on light alloys of the manganese-copper-aluminium series. Their investigation concerns itself

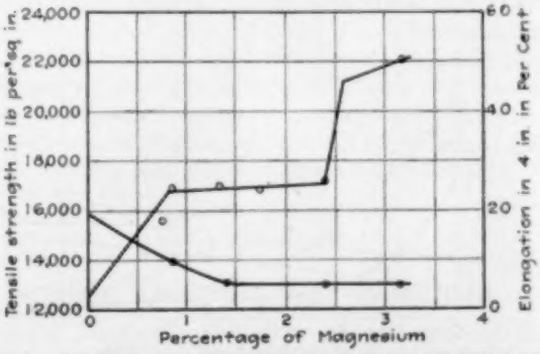


FIG. 16.—EFFECT OF MAGNESIUM ON THE TENSILE PROPERTIES OF ALUMINIUM SAND CASTINGS (LANE)

primarily with the alloys rich in copper; only a few tests were made of the strength of the alloys at the aluminium end of the diagram. Table 9 shows the results of

TABLE IX—TENSILE PROPERTIES OF CAST ALUMINIUM-COPPER MANGANESE ALLOYS

(Rosenhain & Lantsberry, 466)

	Chemical Composition		Tensile Properties — Sand Cast			Chill Cast		
No.	Per Cent Copper	Per Cent Manganese	Tensile Strength Lb. Per Sq.In.	Yield Point Lb. Per Sq.In.	Elongation in 2 In. Per Cent	Tensile Strength Lb. Per Sq.In.	Yield Point Lb. Per Sq.In.	Elongation in 2 In. Per Cent
022	2.15	0.88	13,800	10,400	5	19,100	12,400	6
023	3.11	0.57	15,400	11,200	4	18,500	11,300	3.5
024	3.28	0.98	14,000	11,300	4	18,700	14,200	5
025	1.27	2.06	15,300	12,600	4.7	13,900	13,800	6
026	2.02	1.90	14,300	13,100	3	21,900	13,900	7
026A	2.15	1.91	18,100	14,900	5	22,400	17,500	5
027	2.89	1.76	17,100	14,100	3.5	15,200	13,600	5
028	4.13	1.92	3,200	3,200	2.5	18,600	14,300	3.5

tests of sand and chill castings of different compositions of alloys up to about 4 per cent of copper and 2 per cent of manganese. After making these tests the authors selected two alloys, Nos. 10 and 11, and tested these alloys both in the sand and chill cast condition and as rolled and drawn from ingots 3 in. in diameter. The results of these tests are shown in Table 10. Impact tests made with the Izod machine on rolled alloys showed that the No. 10 required 4.1 ft.-lb. and No. 11, 5.5 ft.-lb. of energy per unit of section in fracture.

TABLE X—THE TENSILE PROPERTIES OF ALUMINIUM-COPPER-MANGANESE ALLOYS
(Rosenhain & Lantsberry 466)

	Tensile Strength Lb. Per Sq.In.	Yield Point Lb. Per Sq.In.	Elongation in 2 In. Per Cent	Reduction of Area Per Cent
ALLOY No. 10, COPPER 2.06%, MANGANESE 1.94%.				
Hot rolled to 1½ in.	36,700	22,000	18.5	39.5
Hot rolled to ¾ in.	38,200	27,100	16.0	37.6
Drawn with annealing to ¾ in.	41,000	25,200	6.0	11.2
Sand cast	19,000	13,000	4.0	....
Chill cast	20,300	14,300	5.0	....
ALLOY No. 11, COPPER 2.89%, MANGANESE 0.94%.				
Hot rolled to 1½ in.	35,300	19,700	20.0	32.8
Hot rolled to ¾ in.	37,000	28,600	15.0	38.0
Sand cast	16,700	13,400	5.0	....
Chill cast	27,000	16,200	13.5	....

The authors conclude that the results on rolled and drawn bars are disappointing and that the superiority found in alloy No. 11 in the form of chill casting was not maintained in the rolled condition. The results show that these alloys have very nearly the same physical properties as the copper-aluminium alloys which were investigated by Carpenter and Edwards.

Alternating stress tests carried out on $\frac{13}{16}$-in. diameter rolled bars of No. 10 and No. 11 alloy gave the following values for the ranges of maximum safe stress under which these alloys would bear an unlimited number of reversals:

Alloy No. 10.....21,000 lb. per sq.in.
Alloy No. 11.....19,700 lb. per sq.in.

The authors also carried out some corrosion experiments on chill castings of two alloys, the results of which are found in the table below.

Alloy Chill Castings of	Loss of Weight Per Sq.Ft. Per Month (30 days) Soap	Water, Lb.	Sea-water, Lb.
Pure aluminium		0.000121	0.0022
Alloy No. 10 (1.9% Mn, 2.06% Cu)		0.000275	0.00042
Alloy No. 11 (0.94% Mn, 2.89% Cu)		0.000128	0.00048

The specimens were machined from castings and immersed for 121 days. The resistance to corrosion in sea-water of the alloys is much superior to that of aluminium. These results are contrary to usual experience with relative corrosion resistance of aluminium and its light alloys (Seligman; discussion).

Tests of resistance to corrosion by sulphuric and nitric acids of alloys of from 1 to 10 per cent Mn showed that these alloys were less resistant to the attack of these acids than pure aluminium.

5. ALUMINIUM-NICKEL AND ALUMINIUM-NICKEL-COPPER

The constitution of this alloy series has been studied by Gwyer (409). A compound, $NiAl_3$, is formed which forms a eutectic with aluminium at 7 per cent nickel, and 630 deg. C. This compound is not soluble in aluminium. A thermal transformation occurs at 550 deg. C. in the alloys containing from 0 to 42 per cent nickel. Reed and Greaves (456, 458) give the results of some tests of these alloys.

The authors have made a study of the properties, microstructure, and corrosion of light aluminium alloys with nickel and copper.

Some preliminary tests of the working properties of such alloys were made. Strips 35 in. in length were rolled cold with the necessary annealings, if possible to a thickness of 0.10 in. and then without further annealing to a strip having a thickness of 0.02 in. Those alloys which were perfectly sound after this treatment and did not crack or break down are comprised within the following percentages:

Copper	Nickel
0.0	4.0
3.5	0.0
2.0	2.0

A portion of each $\frac{3}{8}$-in. diameter rod was turned down to $\frac{3}{16}$-in. diameter and drawn into wire. The diameter at which the drawing had to be abandoned serves as a measure of the relative ductility of the material. Alloys within the following compositions passed through a hole of 0.033 in. in diameter without cracking or hollow drawing:

Nickel	Copper
4	0
0	6
3	2
1	4

TABLE XI—TENSILE PROPERTIES OF ALUMINIUM-COPPER-NICKEL ALLOYS (Read and Greaves, 456, 458)

	Chemical Composition of Chill-Cast Alloys		PHYSICAL PROPERTIES: As Chill Cast				Chemical Composition of Wrought Alloys		Cold Drawn Rods (3)				Annealed Rods (2)				Hot Rolled Rods (1)			
No.	Copper Per Cent	Nickel Per Cent	Tensile Strength in Lb. Per Sq.In.	Yield Point in Lb. Per Sq. In.	Elongation in 2 In. Per Cent	Reduction of Area Per Cent	Copper Per Cent	Nickel Per Cent	Tensile Strength in Lb. Per Sq.In.	Yield Point in Lb. Per Sq.In.	Elongation in 2 In. Per Cent	Reduction of Area Per Cent	Tensile Strength in Lb. Per Sq.In.	Yield Point in Lb. Per Sq.In.	Elongation in 2 In. Per Cent	Reduction of Area Per Cent	Tensile Strength in Lb. Per Sq.In.	Yield Point in Lb. Per Sq.In.	Elongation in 2 in. Per Cent	Reduction of Area Per Cent
23C	....	1.11	14,900	5,800	20.8	36.2	....	1.87	22,700	19,700	12.6	36.9	16,300	5,600	34.1	55.8	18,200	11,900	28.4	52.5
24C	....	2.22	16,900	6,500	16.7	22.1	....	4.31	27,900	22,900	8.5	24.0	20,200	9,900	26.2	42.1	22,300	13,500	22.0	36.4
25C	....	3.38	18,200	7,400	13.5	21.1	2.00	1.12	32,200	26,200	16.0	47.7	23,400	8,300	30.5	56.6	25,400	14,300	27.8	52.0
26C	....	5.52	21,700	9,000	9.0	11.1	1.97	2.22	30,600	26,000	11.8	33.1	22,900	6,300	28.9	44.7	26,600	17,000	21.3	38.6
27C	1.01	1.10	18,200	6,200	19.1	29.2	2.13	3.74	33,900	29,700	7.4	12.4	23,800	6,300	27.2	37.8	28,600	17,900	17.8	29.6
28C	1.00	2.18	18,600	7,400	10.0	15.3	2.10	5.33	37,800	31,700	7.5	15.3	26,500	9,900	25.0	36.3	31,500	18,160	16.0	23.6
29C	1.03	4.03	23,500	8,100	12.1	14.2	4.07	1.12	37,400	31,400	12.1	28.8	29,000	7,400	28.7	44.3	32,000	18,400	20.7	36.9
30C	1.02	5.51	24,800	10,700	6.1	8.5	4.13	2.16	36,300	31,700	8.0	19.3	27,200	8,100	24.8	30.9	30,700	17,900	17.8	28.0
11C	2.04	1.11	21,700	7,200	20.6	24.6	4.07	3.21	34,100	29,900	2.5	3.9	25,400	6,300	22.8	28.0	28,700	17,300	14.6	18.2
12C	1.92	2.18	22,600	8,190	11.4	15.8	4.08	4.30	36,800	29,600	3.8	6.2	25,300	7,200	23.5	29.7	29,500	17,000	13.5	18.6
13C	1.97	3.69	24,500	9,000	7.2	9.2	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....
14C	1.99	5.27	28,600	10,300	5.7	7.4	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....
15C	3.94	1.08	24,100	9,000	7.5	11.7	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....
16C	4.05	2.02	23,400	8,300	6.1	7.0	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....
17C	3.84	3.50	21,200	9,900	5.9	6.9	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....
18C	4.04	4.36	25,200	9,900	4.4	5.0	....	....	.....	.....	....	....	.....	.....	....	....	.....	.....	....	....

(1) 2½ x 18-in. ingot, chill cast, heated to 400 deg. C. rolled hot to 1 in. diameter.
(2) The same annealed at 450 deg. C.
(3) The same as (1) cold drawn to ¾ in. in 2 passes.

Small blocks of metal, 1½ x 1 x 1½ in., were forged down hot to a thickness of ½ in. after heating to 450 deg. C. Those compositions which remained perfectly sound under this treatment were comprised within the following:

Nickel	Copper
7.5	0.0
0.0	5.7
2.0	4.0
5.0	2.0

Tests of the alloys were made as chill cast and as rolled. The chill cast ingots were 1 in. in diameter. For the rolled alloys an ingot was chill cast, 2¼ in. in diameter by 18 in. long, weighing about 7½ lb. This was rolled by the British Aluminum Company to 1-in. diameter rod at about 400 deg. C. A portion of the resulting rod was cold drawn in two passes to ⅞-in. diameter rods. Some of the 1-in. diameter hot rolled rods were annealed. The results of these tests are shown in Fig. 17 and Table XI.

It will be noticed that although the ductility of the alloys of copper-nickel-aluminium in the chill cast and in the rolled state is high, these alloys do not show a very high tensile strength. The highest tensile strength in the series is that of a cold drawn rod containing 2.1 per cent of copper and 5.3 per cent of nickel; the tensile strength of this alloy in a cold drawn state is only 37,800 lb. per sq.in.

The authors made no study of the effect of heat treatment upon rolled alloys.

Tests of the effect of annealing and of quenching on chill cast alloys containing both copper and nickel showed that both annealing and quenching lowered the tensile strength slightly (from 1000 to 2000 lb. per sq.in.) with but slight increase (1 to 1.5 per cent) in elongation.

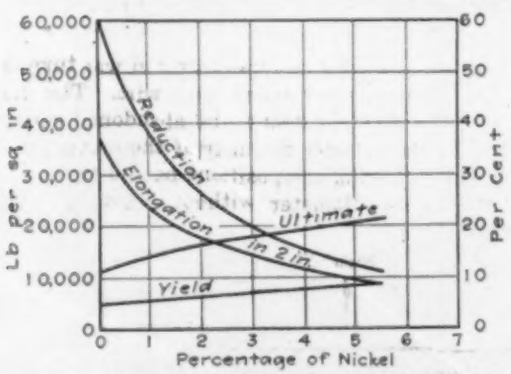


FIG. 17—TENSILE PROPERTIES OF ALUMINIUM CHILL CAST ALLOYS (READ AND GREAVES)

Alternating stress tests made on the Arnold machine showed that the resistance to this test decreases with increase of both copper and nickel content.

TABLE XII—CORROSION OF COLD ROLLED AND OF COLD ROLLED AND ANNEALED SHEETS OF ALUMINIUM-COPPER-NICKEL ALLOYS

(Read and Greaves, 456)

Chemical Composition		Loss of Weight in Lb. Per Sq.Ft. Per Month			
		Sea Water		Fresh Water	
Copper Per Cent	Nickel Per Cent	Annealed	Cold Rolled	Annealed	Cold Rolled
Aluminum		0.00045	0.00041	0.00014	0.00020
Same—remelted		0.00024	0.00039	0.00014	0.00018
1.90		0.00038	0.00059	0.00138	0.00150
2.00	1.12	....	0.00047	0.00111	0.00138
1.97	2.22	0.00064	0.00050	0.00106	0.00090
2.13	3.74	0.00043	0.00099	0.00123	0.00117
2.10	5.33	0.00050	0.00138	0.00108	0.00057
3.76	....	0.00045	0.00050	0.00229	0.00238
4.07	1.12	0.00058	0.00097	0.00162	0.00165
4.13	2.16	0.00046	0.00083	0.00169	0.00154
4.07	3.21	0.00118	.....	0.00172	0.00151
4.08	4.30	0.00102	0.00073	0.00154	0.00133
....	1.42	0.00092	0.00104	0.00030	0.00037
....	2.25	0.00077	0.00042	0.00045	0.00033

The authors carried out corrosion tests both in sea- and in fresh-water on plates, both cold rolled and annealed, 2 x 1 x 0.15 in. Their results are given in Table 12. The results show that the alloys although inferior to pure aluminium in their resistance to corrosion are somewhat superior to other types of alloys in this respect; copper appears to accelerate corrosion more than nickel.

The authors also observed that the superiority shown by the nickel-aluminium alloys to ordinary corrosion in water was not maintained when dilute vinegar, oxalic acid, citric acid and tartaric acids were used.

The authors draw no general conclusion from their work but it is evident that the alloys of the compositions which they studied do not show a great enough strength to be considered as an alloy to be rolled into structural shapes. All the compositions were definitely inferior to duralumin.

On the other hand, the chill cast alloys look somewhat more promising and in view of the superior resistance to corrosion of the alloys of nickel and aluminium over those of copper and aluminium, may compete with the latter series in this form.

6. ALUMINIUM-SILICON

Fraenkel (420) has investigated the aluminium-silicon equilibrium. These metals form a simple eutectic series with the eutectic at 10 per cent (atomic) of silicon and at 580 deg. C. Silicon is not soluble in aluminium to the extent of more than approximately 0.5 per cent.

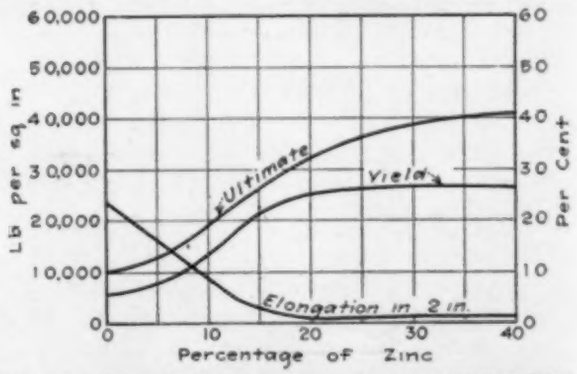


FIG. 18—TENSILE PROPERTIES OF ALUMINIUM—ZINC SAND CAST ALLOYS (ROSENBAIN AND ARCHBUTT)

Schirmeister (see below) gives the results of some mechanical tests of aluminium-silicon alloys.

7. ALUMINIUM-ZINC

The constitution of this series of alloys has been studied by Lorenz and Plumbridge (436), Rosenhain (439), Shepherd (447) and others. Aluminium and zinc form a eutectiferous series, the eutectic lying at 95 per cent of zinc and 380 deg. C. A compound, Al_2Zn_3, is formed decomposing at 256 deg. C. Aluminium takes up approximately 40 to 20 per cent of zinc in solid solution, depending on the temperature.

The principal investigation of this alloy series is that of Rosenhain and Archbutt (438), who besides their study of the constitution of the alloy series carried out tensile, impact and alternating stress tests of cast and wrought alloys. The tensile properties were studied at

higher temperatures, and corrosion tests made on castings.

In Fig. 18 are shown the results of tensile tests of sand cast alloys of aluminium-zinc prepared by melting in an oil furnace, care being taken to keep the temperature below 800 deg. C.; the castings were 7 in. long by $\frac{3}{8}$ in. in diameter. It is seen that the tensile strength of the alloys increases with the percentage of zinc. In Fig. 19 are shown the results of tensile tests

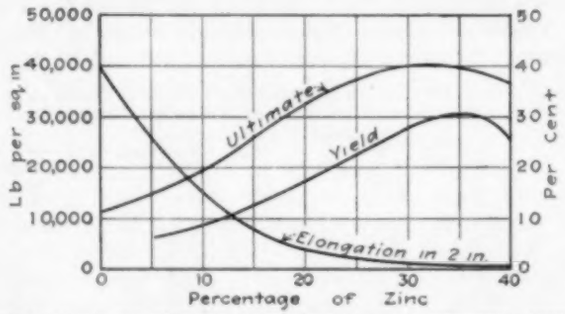


FIG. 19.—TENSILE PROPERTIES OF ALUMINIUM—ZINC CHILL CAST ALLOYS (ROSENBAIN AND ARCHBUTT)

of chill cast alloys poured into a chill mold 7 x $\frac{3}{4}$ in. in diameter. It will be noted that the strength of such chill castings is slightly greater at all compositions than that of the sand castings; this is due primarily to the greater density of such castings.

The authors made some tests to determine whether the cast alloys of this series were subject to spontaneous disintegration. A certain number of sand cast specimens of zinc contents varying from 9 to 75 per cent were laid on one side when the alloys were originally made and tested. These were tested after an interval of fifteen months, . . . and it was found that there was no sign whatever or any disintegration, so if these alloys are subject to any aging process at all it must be of an extremely gradual character. It was found, however, that in every case there had been an increase of tensile strength, varying from 500 to 4000 lb. per sq.in., accompanied in some cases by decrease, in others by increase of elongation.

This agrees with practical experience with these alloys in that immediately after casting they are not readily machined, but "drag"; after aging for a few weeks a marked improvement in machinability occurs.

"Compression tests on both sand and chill castings showed that in general the compressive strength of these alloys is approximately proportional to their tensile strength, although the yield points in compression are also decidedly lower than the ultimate strength in tension."

In the discussion on this paper, Seligman (British Aluminum Co., Ltd.) states that the reason why composition above from 13 to 14 per cent of zinc had not hitherto been used for casting purposes was that it was the experience of the manufacturers that such alloys were sensitive to vibration and shock and hence not suitable for the motor industry.

Ingots were prepared of different compositions, 20 in. long and 3 in. in diameter. They were heated to approximately 400 deg. C. and hot rolled to $1\frac{1}{4}$, $\frac{7}{8}$ and $\frac{1}{2}$ in. respectively. The 25 per cent zinc-aluminium alloy could fairly readily be rolled, but the 30 per cent alloy cracked considerably, even upon rolling it to $1\frac{1}{4}$ in. in diameter, so that 25 per cent may be looked upon as the maximum composition that can be rolled.

For some of the later series a rolling temperature of from 315 to 364 deg. C. was used with better results than at the higher temperatures. Some other experiments on the malleability of these alloys under the hammer at higher temperatures showed that the malleability increased with increase of temperature up to 400 deg. C., but that at 450 deg. C. the test specimen cracked, and at 500 deg. C. broke into coarse powder.

Samples of the $1\frac{1}{4}$-in. hot rolled bars were used for cold drawing experiments, the object aimed at being to reduce them by steps of $\frac{1}{16}$ in. down to a diameter of $\frac{3}{4}$ in. Compositions up to 15 per cent stood this cold drawing well. Above that the samples either drew hollow or broke.

The 15 and 20 per cent alloys were cast into slabs measuring $13\frac{1}{2}$ x $10\frac{1}{2}$ x $\frac{1}{2}$ in., heated to 400 deg. C., cooled to 300 deg. C., hot rolled to 0.13 in., annealed at 400 deg. C. and cold rolled to 0.7 in. The 15 per cent alloy behaved satisfactorily under this treatment. The 20 per cent alloy exhibited a small amount of cracking at the edge of the sheet, a defect which may have arisen from roughness of the original casting.

Fig. 20 shows the results of tests of hot rolled bars $1\frac{1}{4}$ in. in diameter. These alloys exhibited a well-defined yield point accompanied by a sharp drop of the beam of the testing machine, similar to that found in the testing of mild steel. Similar curve series were obtained showing the results of tensile tests of hot rolled bars, $\frac{7}{8}$ in. and $\frac{1}{2}$ in. in diameter. The results of the former series are shown in Fig. 21. The curious fact is definitely ascertained that the alloys containing more than 15 per cent of zinc appear to deteriorate when a large amount of work is put upon them. It is seen that

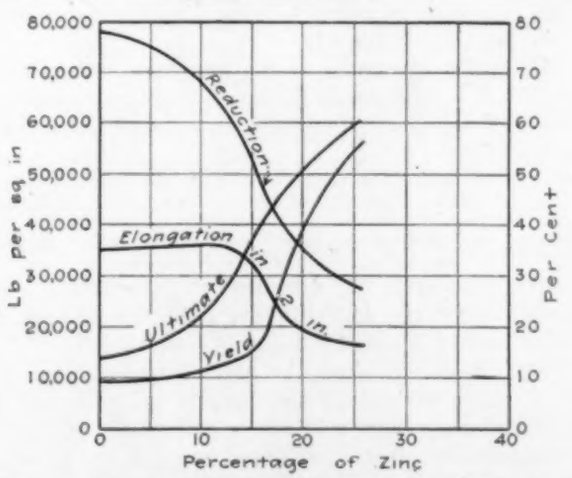


FIG. 20—TENSILE PROPERTIES OF ALUMINIUM—ZINC ALLOYS; $1\frac{1}{4}$-IN. HOT ROLLED BAR (ROSENBAIN AND ARCHBUTT)

although for compositions below 15 per cent of zinc the strength of the $\frac{7}{8}$-in. diameter rod is higher, as might be naturally expected, than that of the $1\frac{1}{4}$-in. diameter rod, above that percentage the reverse is true.

A study of the tensile strength of hot rolled and annealed bars shows that for compositions between 13 and 20 per cent the application of work upon the alloys appears to have beneficial effect, which is not entirely removed by annealing. The results on one series are shown in Fig. 21. In considering the strength of cold

drawn bars drawn to $\frac{13}{16}$-in. diameter from the hot rolled 1¼-in. diameter rods, it is most remarkable that the ultimate strength of the cold drawn bars is very little higher than that of the original hot rolled bars from which they were drawn; it is noted that the alloys higher in zinc (above 15 per cent) show a lower ultimate strength in the cold drawn than in the hot rolled state.

Tests made on wire, 0.128 in. in diameter, as cold drawn, show that the strength of such wire is considerably above that of any other form of the same material until a composition of 20 per cent of zinc is reached; thereafter the strength of the wire is less than that of the original 1¼-in. hot rolled bars.

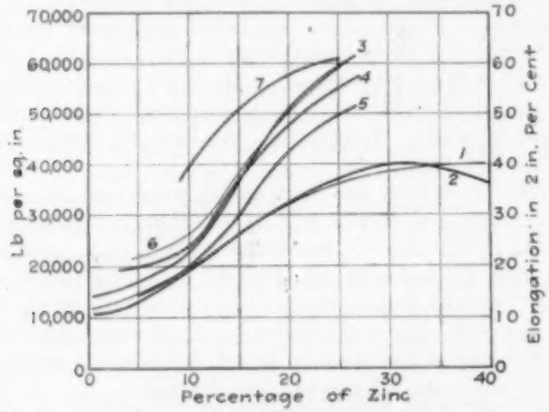


FIG. 21.—TENSILE PROPERTIES OF ALUMINIUM—ZINC ALLOYS (ROSENBAIN AND ARCHBUTT)

"We thus arrive at the very remarkable result that no amount of further work, whether applied to the metal when hot or cold, increases the tensile strength of the 25 per cent alloy beyond that which is attained in the form of 1¼-in. hot rolled bars, the only marked effect of cold work being to bring about some reduction in the ductility of the alloy."

The tensile strengths of the two compositions rolled out into sheet 0.07 in. in thickness were very nearly the same as those obtained on bars, drawn with annealing as shown below:

Fifteen per cent alloy sheet, as rolled and tested longitudinally—tensile strength 47,000 lb. per sq.in.; elongation 1.5 per cent in 2 in.

Twenty per cent alloy sheet, similarly—tensile strength 50,500 lb. per sq.in.; elongation 0.5 per cent in 2 in.

After annealing at 400 deg. C., these two alloys showed 33,000 and 43,000 lb. per sq.in. tensile strength, and 24 and 10 per cent elongation, respectively.

Figs. 20 and 21 show the specific tenacity, the tensile strength divided by the density, of sand cast and hot rolled aluminium-zinc alloys and of hot rolled aluminium-copper alloys, the latter being taken from the data by Carpenter and Edwards. It will be noted that the aluminium-zinc alloy of 20 per cent shows a greater strength per unit mass than the highest strength alloy recorded by Carpenter and Edwards for the light aluminium-copper alloys.

Alternating stress tests carried out with alternations of direct stress on specimens cut from ⅝-in. diameter hot rolled bars gave the following results:

Per Cent Zinc	Maximum Safe Range of Stress Lb. Per Sq. In.[1]
5	11,200
9	15,000
11	19,200
17	22,400
26	26,900

[1]Giving about 1,000,000 reversals to rupture.

Impact tests carried out on the Izod machine gave the following results:

Per Cent Zinc	Ft. Lb. Per Sq. In. Absorbed in Rupture
5	3.9
9	4.3
13	5.4
15	5.8
17	5.75
20	5.8
26	4.1

Tensile tests were carried out at higher temperature on several of the alloys. Some of the results are given in Table 13 below. Determinations made of the coefficient of thermal expansion between 0 and 18 deg. C.

TABLE XIII—TENSILE PROPERTIES OF ZINC-ALUMINIUM ALLOYS IN FORM OF ½-IN. ROLLED BARS AT HIGHER TEMPERATURES

(Rosenhain & Archbutt, 438)

Temp. Deg. C.	Tensile Properties: Tensile Strength Lb. Per Sq.In.	Yield Point Lb. Per Sq.In.	Elongation in 2 In. Per Cent
	Alloy of 13% Zinc		
18	32,100	15,700	31
50	28,500	18,350	30
75	24,000	17,350	29
100	20,650	15,200	33
150	16,000	13,600	34
200	11,900	11,100	48
	Alloy of 25% Zinc		
18	55,600	44,300	20
50	50,800	40,100	21
75	45,700	34,400	21
100	41,000	33,200	21
150	35,300	30,200	19
200	24,600	21,800	18

of these alloys in the form of $\frac{13}{16}$-in. diameter rolled bars yielded the following values:

Per Cent Zinc	Coefficient of Thermal Expansion
5	0.0000227
15	0.0000231
20 (½-in. bar)	0.0000234

Sand and chill castings 3 x 4 x ⅜ in. were machined and exposed for 521 days to the action of sea-water. The losses in weight were measured and are given in the table below:

Corrosion of Zinc-Aluminum Alloy Castings

Per Cent Zinc	Loss of Weight in Lb. Per Sq.In. Per Month: Chill Castings	Sand Castings
5	0.0012	0.00054
9	0.0017	0.00092
13	0.0018	0.00062
15	0.0023	0.00145

The sand castings were thus superior to the chill castings in this respect.

In the appendix to this report the authors describe an alloy consisting of 25 per cent of zinc, 3 per cent of copper and 62 per cent of aluminium. This alloy shows a tensile strength of about 41,000 lb. and 45,000 lb. in the sand and chill cast condition, respectively. The rolling of this alloy presents considerable difficulty but if careful temperature control is exercised it can be hot rolled. This alloy gave a tensile strength, in the form of 1¼-in. hot rolled bar, of 71,000 lb. per sq.in., a yield point of 61,000 lb. per sq.in. and an elongation in 1 in. of 21 per cent. The specific gravity of this alloy is 3.29.

Summarizing the work of these investigators on the physical properties at ordinary temperatures, the following points may be noted:

1. It has been found possible to roll out into bars and even to draw into wire an alloy containing as much as 26 per cent of zinc. This alloy attains its maximum tensile strength when in the condition of hot rolled bars 1¼ in. in diameter, the maximum strength being 62,000 lb. per sq.in. This alloy has a density of 3.24 when hot rolled.

2. Further rolling down of this alloy does not improve, but impairs, the tensile properties of the material.

3. Both the binary and ternary alloys referred to differ from the majority of non-ferrous alloys in the fact that in the rolled condition they exhibit a definite and well-marked yield point similar to that of mild steel.

4. A great defect of this group of alloys is their great sensitiveness to rise of temperature in relation to their tensile strength. Thus the alloy containing 25 per cent of zinc loses 33 per cent of its tensile strength (at 20 deg. C.) when the temperature is raised to 100 deg. C. The highest tensile strength of the cast alloys determined was 42,000 lb. per sq.in. for an alloy containing 50 per cent of zinc; the highest for the wrought alloys was that of the 1¼-in. hot rolled bars of 26 per cent zinc content and having a tensile strength of 62,000 lb. per sq.in., a yield point of 56,000 lb. per sq.in. and an elongation of 16.5 per cent in 8 in.

5. Tests made of the resistance of these alloys to alternation of direct stress gave a series of results for the safe range of alternating stresses which lies considerably below that of the static elastic limits. The 25 per cent alloy showed a safe range of 27,000 lb. per sq.in. Single-blow impact tests made on the Izod machine showed that the work absorbed by fracture reaches a maximum for a zinc content lying between 15 and 20 per cent; this, for an alloy containing 15 per cent of zinc, is 5.8 ft.lb. Under Prof. Arnold's alternate bending tests the endurance of the alloys falls rapidly with the increase of zinc content.

Organizing Research Work on a National Scale

THE proposal has been many times made that the work of scientific and technical research, now carried on independently by a multitude of institutions and individuals, should be organized on a national scale. Such an organization, could it be effected, would make unnecessary a vast amount of needless duplication of work. It would further be possible, by concentrating research workers on a particular task, to make much more rapid progress; and by giving the results of successful research greater prestige and standing, it would be possible to secure the adoption of new developments in practical work to a much greater extent than at present. The magnitude of the task of controlling and coördinating the research work of the entire country is such, however, that no serious attempt to do this has ever been undertaken until the war brought the need and opportunity home.

Two years ago President Wilson accepted an offer by the National Academy of Sciences to undertake the organization of the scientific resources and research facilities of the country. The National Research Council was organized, in accordance with this offer, a year in advance of this country's actual declaration of war, and it was officially recognized by the Council of National Defense and arranged to serve during the war as a department of that body early in 1917.

While the National Academy of Sciences, from which the National Research Council sprung, deals only with so-called "pure" science, it was recognized from the outset that the business of the Council was to promote research which aimed at definite, practical results.

The Executive Order of President Wilson, issued on May 11, recognized the work which has already been accomplished by the Council and ordered the coöperation with it of the scientific and technical branches of the Government. The practical nature of the Council's work was attested at the outset by the fact that its first financial support came from the Engineering Foundation; and is attested now by the fact that Governmental appropriations to the amount of $270,000 have been made to finance special branches.

The work accomplished by the Council and its organization and plans were the subject of an address by the Council's Chairman, Dr. George Ellery Hale, delivered on May 28 before a joint meeting of the National Engineering Societies in New York City.

As much of the research directed by the Council relates to apparatus useful in the war, detailed statements concerning such work cannot be made public. It can be said, however, that among the problems with which the Council is dealing are processes for making nitrates, the manufacture of optical glass, materials conveniently located for highway construction along the Atlantic coast, methods of combating the submarine, the development of body armor, range finders, location of enemy heavy artillery by sound, psychological tests of recruits. These are but samples at random of the numerous fields in which committees of the Council are at work.

Dr. Hale, in his address, emphasized that the Council recognizes the great value of individual initiative and direction. It will aim to coöperate with and aid the individual worker and not to supersede him. A statement of Dr. Hale's which won hearty applause from his audience was the following:

"It should be said here, once for all, that the policy of the National Research Council has been from the outset invariably to recommend the immediate development and utilization for military and naval purposes of the best devices or methods known at the time, with the understanding that research for the purposes of improving such devices should not retard production demanded to meet pressing military needs."

In the special work of coöperating with existing research agencies, a census has been made under direction of Dr. S. W. Stratton, Chief of the Bureau of Standards, of the research workers and facilities in the universities, manufacturing plants, Federal Government bureaus, commercial testing laboratories, etc., throughout the United States. Another committee, of which Dr. John C. Merriam of the University of California is Chairman, has secured the organization of local research committees in 72 universities and colleges to coöperate with the National Council and in many cases with local industries.

There has also been organized with the approval and coöperation of the Secretaries of War and the Navy, a committee to interchange technical information and the results of research work with the authorities of Great Britain and France. This committee has offices in Paris, London and Washington. Dr. W. F. Durand represents the committee in Paris and Dr. H. A. Bumstead in London. The Council of National Defense has provided funds to the amount of $38,400 for this committee's work for the current year.

Synopsis of Recent Chemical and Metallurgical Literature

A New Illuminator.—The travel of the source of light in an ordinary arc, its flicker, poor color distribution and need of constant adjustment when used as a mode of illumination for microscopic, photographic, or projection work may apparently be obviated by the substitution of gas-filled lamps, according to a description published in *Electrical World* by R. P. BURROWS and J. T. CALDWELL, of the Engineering Department of the National Lamp Works of the General Electric Co. The

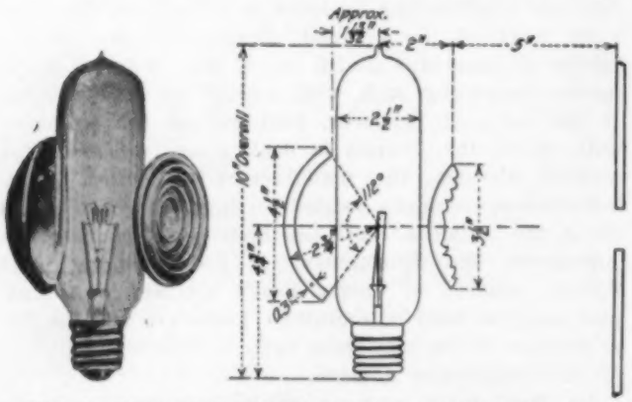


FIG. 1.—RELATIVE POSITIONS OF GAS-FILLED LAMP, MIRROR AND CONDENSER FOR PROJECTION PURPOSES

inherent limitation of the filament lamp, that is, the relatively low intrinsic brilliancy of the source has been limited by the life of the filament—the higher the temperature the shorter the life and the greater the candle power emitted per unit area of filament; and second, limited by the diameter of the filament—in general the greater the diameter of the filament the higher the operating temperature for the same life. With gas-filled lamps the brilliancy is limited to about one-fourth that of a good direct-current arc, so the success with which

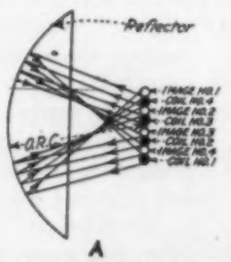


FIG. 2.—IMAGE OF FILAMENT FALLS BETWEEN COILS GIVING SOLID PLANE OF LIGHT

the light is projected depends upon the utilization of the light. The optical properties of the condensing lens evidently limits the effective size of the light source available. For this reason the "monoplane" filament has been developed, and is so arranged that all of the coils are in one plane. This construction allows most of the filament to come within the focus area of the lens system. The light from the rear portion of the filament is gathered and redirected as useful light by a spherical mirror (see Fig. 1). As shown in Fig. 2 images from the filament can be made to fall at points between the filament coils, which gives a solid plane of light as photographed in Fig. 3. It may readily be seen that if a large bulb were to be used to inclose the filament, advantage could not be taken of the short-focus condensing lens (a prismatic lens of the Fresnel type with a 76-deg. solid angle is used); consequently it is necessary to use a bulb of as small a diameter as is practically possible. This bulb is tubular and of such length that the fine particles given off by the filament are carried upward by the hot gas and deposited on a portion of the bulb well out of the zone of useful light.

In obtaining concentration of filament it is necessary to get as high a wattage and filament brilliancy as possible for the size of light source previously determined. This can be most easily accomplished by the use of a large diameter wire, or, in other words, through the

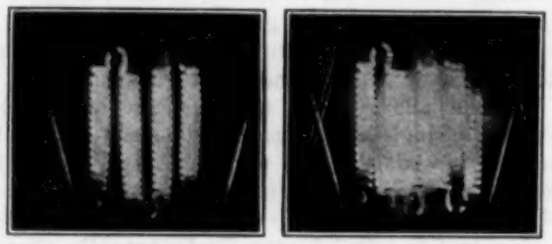


FIG. 3.—FILAMENT ALONE AND WITH IMAGE BETWEEN COILS

use of a high-current, low-voltage lamp. This is objectionable from one standpoint, in that it cannot be used on regular lighting circuits.

A transformer has been developed which can be used on 110- to 120-volt and 220-volt alternating-current circuits. This transformer includes a variable resistance, or a reactance, in the primary circuit to take care of the variations in line voltage, thus enabling the operator to maintain the normal current on the lamp. An ammeter is placed in the secondary circuit of the transformer, and a four-point starting switch is included in some equipments. This switch eliminates the possibility of a rush of current through the cold lamp when the current is first applied, for the connections are such that the current is gradually increased as the switch is thrown in.

Strength of Oxyacetylene Welds.—In Bulletin 98, University of Illinois, Prof. H. F. MOORE describes the results of tests performed on oxyacetylene welded joints in mild steel plates. The joints were made by skilled workmen, and should therefore be regarded as better than the joints made in ordinary welding shops. The static tension tests showed a joint efficiency of 100 per cent in plates one-half inch thick or less, decreasing with thicker plates. The joints were strengthened by working after welding, but were weakened by annealing at 800 deg. C. The efficiency of the material is always less than the efficiency of the joint, indicating the necessity of building up the weld to a thickness greater than that of the plate. Alternating stress tests follow in a general way the results given by static testing. Under impact the joints are decidedly weaker than the original material; for points welded with no subsequent treatment the strength under impact is about half that of the plate. If the weld is worked while hot the impact resisting qualities are slightly improved, while annealing at 800 deg. C. has little effect.

Gases, Oxides and Blowholes in Admiralty Bronze.—Prof. H. C. H. CARPENTER and Miss C. F. ELAM have experimented in the foundry of Mr. J. Dewrance, originator of this alloy, and presented their findings before the March, 1918, meeting of the Institute of Metals (British). They cast 3¼-inch square ingots, 6 inches long at various temperatures determined by a thermocouple in the crucible at the time of pouring. For examination, the ingots were cut in half and machined in a special way to obviate the use of etching reagents, which would tend to increase the size of blowholes and other physical defects. A cut of 0.01 inch depth is taken with a feed of 0.01 inch with a very sharp square-pointed tool 0.01 inch wide.

They find that unsoundness was always associated with high temperature of pouring, irrespective of the kind of copper used—sand cast ingots showed a few large holes, while chill casting developed a multitude of minute ones. By alternately pouring from about 1400 deg. C. and allowing the metal to cool in the crucible to 1225 deg., the same metal is rendered alternately unsound and sound. The actual casting operation, therefore, provided the temperature is sufficiently high, is the deciding factor in producing sound ingots, and KARR and RAWDON'S conclusions in *Technologic Papers* of the Bureau of Standards, No. 59, that the best results could be obtained by pouring within the range of 1120 and 1270 deg. C. is confirmed in general. Melting and casting *in vacuo* is uncommercial, and would not eliminate all the gas introduced with the cold metal. Holding the melting furnace at 1270 deg. is impracticable owing to the reduction in the speed of melting. The action of scavengers and deoxidizers is still uncertain. The best way is to measure the temperature of each crucible before pouring by proper optical pyrometers—practice

FIG. 1.—OXIDE INCLUSION, CONSISTING OF TWO OXIDES, UNETCHED; x 500

FIG. 2.—OXIDE INCLUSION, UNETCHED; x 500

of this method should be easy in comparison with that of progressive steel makers who try to control the temperature of casting to within 20 deg. at 1600 deg. C.

Figs. 1 to 4 show various inclusions of oxides found on microscopic examination. These are often associated with the delta copper-tin constituent—the light portion of Fig. 2. The rhombohedral inclusions of Fig. 3 occurred in metal often remelted and containing little or no zinc. One would expect the copper oxide formed in melting to be reduced by zinc and tin when they are added; the oxides of the two latter being insoluble, collect and liquidate as mechanical impurities, much of their quantity being skimmed off the melt before pouring. It is very difficult to distinguish between tin and zinc oxides. Ferric chloride and hydrochloric acid will dissolve the zinc oxide, but will not attack the other.

The authors conducted many experiments to determine the composition of the gases filling the blowholes (evidently reducing in nature by the brightness of the cavity walls). Their results were somewhat variable. The small volume of gases obtainable was given off very

FIG. 3.—OXIDE INCLUSION, UNETCHED; x 500

FIG. 4.—OXIDE FILMS, UNETCHED; x 500

slowly, was of complex nature approximating the furnace atmosphere, and varied in composition depending upon the method of collection. If the gas is removed as quickly as it comes off, it has a smaller volume, its chief characteristics being a large percentage of sulphur dioxide and hydrogen sulphide and a small percentage of hydrogen; if, on the other hand the gas is removed slowly or heated for a long time in contact with the hot tube and metal, the volume is larger than in the former case. There is then a large percentage of hydrogen, and the sulphur dioxide and hydrogen sulphide are either low or entirely absent. The zinc is largely responsible for this change, as there is much less difference in the gases collected in the two ways from pure furnace-refined copper. Zinc may act in this manner by lowering the solubility of the gases in the alloy, or by volatilizing *in vacuo*, reacting with the sulphur forming zinc sulphide which forthwith condenses on the inside of the tube. There is no outstanding difference between the gases collected from sound and unsound castings which would account for the presence or absence of the blowholes. It cannot be concluded from their experiments that there is any gas present in the metal poured too hot that is not in sound metal, nor does it appear that there is a larger volume of any one gas or gases present in the one than in the other. Experiment showed that there is a drop of about 100 deg. C. in the temeprature of the metal in passing from the crucible to the mold. The explanation appearing most probable is based on the fact which they have established that this mixture of gases can exist in more than one form, each possessing its characteristic volume and composition. The sudden change in temperature of the alloy on pouring is sufficient to cause a reaction or a decomposition of certain of the gases, with the formation of another gas mixture with a relatively large volume which is insoluble in the alloy.

Recent Chemical and Metallurgical Patents

Ammonia by Hydrogenation of Nitrogen.—The processes for the production of synthetic ammonia by the hydration of aluminium nitride and calcium cyanamide are well known commercially. MR. CARLETON ELLIS, of Montclair, N. J. (assignee, C. S. Lutkins, Rye, N. Y.), has patented a more direct process passing a mixture of nitrogen and hydrogen at high pressures and temperatures (40 atm., 500 deg. C.) in volume proportions of one to three over catalytic materials of the type of nickel-cobalt carbides whereupon a chemical reaction takes place producing synthetic ammonia. (July 23, 1918; 1,273,772.)

Process of Producing Cyanamides.—VICTOR THRANE, of Christiania, Norway, patents the use of the Hoffmann Ring furnace, together with the sifting of inert materials over the furnace conveyors in order to prevent the fusion of the carbides thereon during the nitriding of the calcium carbide. The conveyor moves the carbide charge countercurrent to the flow of nitrogen and is so speeded that time for completing the reaction is allowed in approaching and passing through the fired zone. The use of the inert intermediate material expedites the discharge of the conveyor. In the many installations of these furnaces in the German pottery works, sand has been universally used to protect the metal mechanical parts, it having the property of flowing readily when hot. (July 23, 1918; 1,273,690.)

Production of Nitrogen.—The process of removing oxygen from air by combustion with hydrogen in a gas engine and utilizing the force of the reaction in generating electromotive force for the electrolysis of water to maintain a continuous supply of hydrogen has been patented by MR. CARLO ANDREUCCI, of Rome, Italy. He has successfully practiced this process by bringing about by means of an electric spark the explosion of successive charges each of substantially 1000 liters of air (containing 209 liters of oxygen) with 418 liters of hydrogen, in the combustion cylinder of an internal combustion gas engine provided with an electric spark plug. The proportions given may be determined or regulated by operation of the throttling inlet valves, one for air and the other for hydrogen. About 336 grams of water and 778.3 liters of nitrogen mixed with oxides of carbon, argon, etc., are obtained per 1000 liters of air. (July 9, 1918; 1,272,181.)

Depolarization by Sulphur Dioxide.—F. E. STUDT, of London, England, notes that it is undesirable to utilize the ferrous salts contained in solutions from leaching copper ores as a depolarizer when electrolyzing them, because the reaction,

$$CuSO_4 + 2FeSO_4 = Cu + Fe_2(SO_4)_3,$$

is reversible, the ferric sulphate formed corroding the cathode copper, thus lowering the ampere efficiency. Using SO_2 as a depolarizer prevents this effect, requires a lower cell voltage, and generates sulphuric acid. He therefore specifies the use of solutions properly reduced, containing little or no ferric iron, and saturated with SO_2. Proper cell conditions require constant circulation, a low current density (13 amps. per square foot) and a temperature of 49 to 53 deg. C. Liquid sulphur dioxide, readily made from smelter gases, is gasified, and introduced to the electrolytic tanks under a pressure of two to four atmospheres with a sufficient quantity of steam to maintain the temperature of the electrolyte in the required range. These gases enter through a grid of perforated lead pipes laid on the floor of the tanks, and placed in such a manner that a stream of bubbles impinges on both sides of each anode. This delivers the depolarizing agent to the exact place where it is needed, and maintains correct agitation. The steam effectually prevents the formation of crystalline growths tending to plug the small openings. The overflow from the electrolytic tanks is thus saturated with SO_2, which, if sufficiently long time is given in the leaching tanks, will reduce any ferric salts formed during that part of the cycle. (1,260,830; Mar. 26, 1918.)

Electrode Construction.—JAMES B. HERRESHOFF, Jr., of Richmond Hill, New York, notes that the circulation of the electrolyte tends to carry small particles of impurities from the copper anode over to the cathode, where they lodge and thus contaminate the resulting deposit. It has been proposed to hang bi-polar electrodes

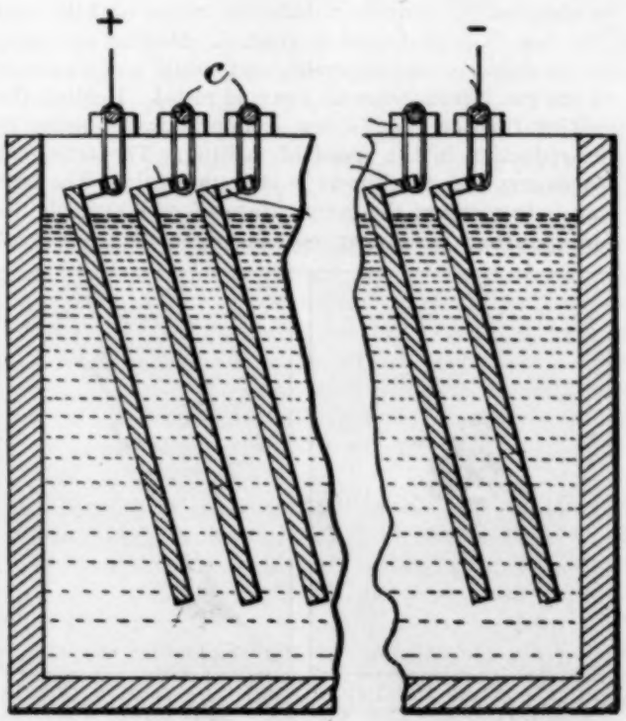


FIG. 1.

at an inclination, so that the cathode side is inclined downward, thus minimizing the tendency of any wandering slime particle to adhere. The inclination has ordinarily been effected by resting the lower end of the electrode against cross bars, which offer obstruction to the free settlement of slime, causing an accumulation of such material sufficient to short circuit portions of the cell. The inventor proposes to hang the electrodes freely in the solution at a proper and parallel inclination by casting an offset ear to the top, as shown in Fig 1. (1,262,045; Apr. 9, 1918.)

A Permeameter for General Magnetic Analysis

By Frank P. Fahy

THE writer has described[1] a permeameter for general magnetic testing in the use of which the difficulties formerly encountered in accurately and rapidly determining the magnetic properties of materials have been largely overcome. This apparatus calls for but one compensating adjustment and is so adapted that it may be used to simultaneously compare the properties of two specimens, one of which partakes of the character of a standard, or to measure the properties of a single specimen. The extended use of this permeameter in investigative work has disclosed that where a simultaneous comparative measurement is not required a great gain in simplicity of construction and ease of manipulation is possible without departing from the principle of operation or sacrificing accuracy. The new permeameter has no compensating adjustment and calls for no previous experience in magnetic testing on the part of the user.

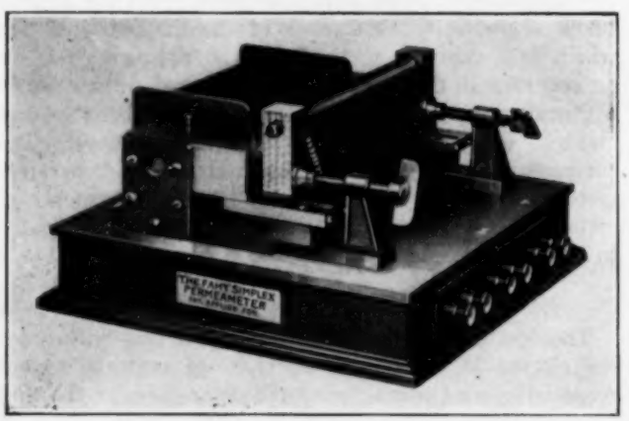


FIG. 1.—SIMPLEX PERMEAMETER

Fig. 1 shows the new permeameter in standard form as arranged to take specimens from ten inches in length upward.

The Magnetic Circuits

In Figs. 2 and 3 are shown the permeameter in plan and elevation. *A* represents the base of the apparatus upon which is mounted a magnetic core of U-shape, consisting of a yoke portion *B* and core arms *C* and *C'*. In the operation of the instrument the polar faces of these core arms are bridged by the material under test. The core is mounted upon supporting members *a* of non-magnetic material which are secured to the base *A*, the core arms being fastened to *a* by bracket members *a'* and core arm extensions a^2. The core arm extensions a^2, which are of magnetic material, are attached respectively to the outer portions of the core arms *C* and *C'* and to the supporting members *a* and bring about magnetic contact with the edge portion of the test specimen when the latter is of solid rectangular or lamellar sheet form.

I and *I'* are magnetic contact shoes to the lower ends of which are attached supporting blocks of non-magnetic material a^3 which engage with slots cut in the extensions a^2 and serve to permit movement of *I* and *I'* toward and away from the pole faces of the core arms *C* and *C'*. The purpose of the supporting blocks a^3 is to retain the contact shoes *I* and *I'* at a definite distance from the extensions a^2 and to prevent magnetic

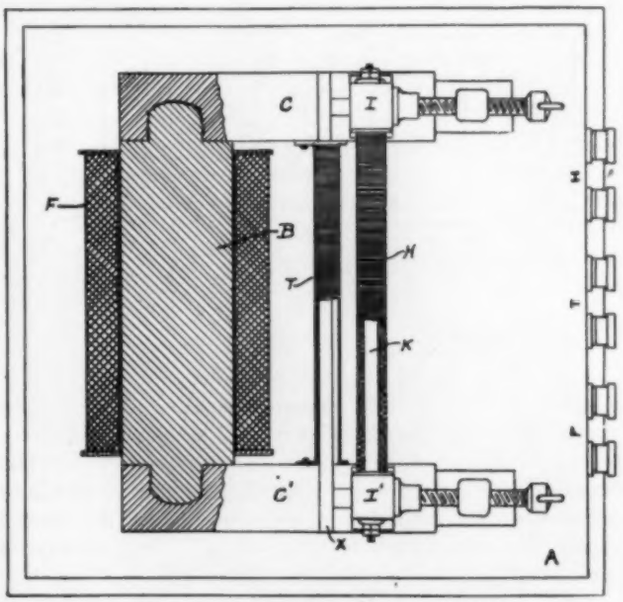


FIG. 2.—PERMEAMETER IN PLAN

contact therewith. Clamp supports a^4 of non-magnetic material are secured to the base *A* adjacent to the polar faces of the core arms *C* and *C'* and are provided with clamping screws *D*.

Upon the yoke portion *B* of the magnetic core is located a magnetizing coil *F*. A test coil *T*, within which the specimen under test is inserted, is situated at the ends of the core arms *C* and *C'*. A second test coil *H*, which is wound upon a solid non-magnetic core *K*, is affixed between the upper ends of the contact shoes

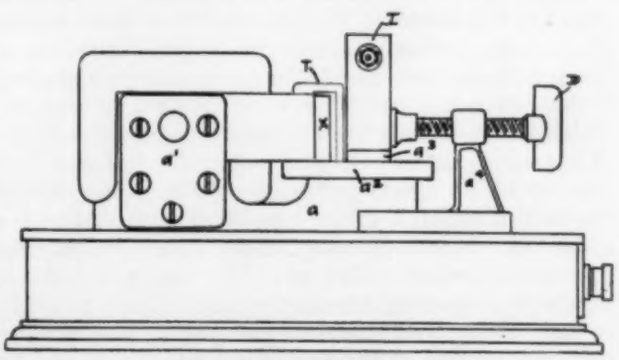


FIG. 3.—PERMEAMETER IN ELEVATION

I and *I'*. Fig. 4 shows diagrammatically the flux path within the core due to the magnetomotive force generated by current in the coil *F*. In practice this current is usually supplied by a storage battery. The magnetic field due to the current has the direction indicated by the arrows, or the reverse, according to the direction of flow of the current in the coil *F*.

Electrical Connections

Fig. 4 also shows diagrammatically the electrical connections of the permeameter. The magnetizing coil is connected to the terminals marked *F*, the test coil *T*

[1] Fahy, "A Permeameter for Magnetic-Mechanical Testing," *Electrical World*, Vol. 69, p. 315, 1917. See also "An Experimental Study of the Fahy Permeameter," Scient. Paper No. 306 of the U. S. Bureau of Standards.

to the terminals marked *T* and the test coil *H* to the terminals marked *H*. The terminals *F* are connected, externally to the instrument, to a source of electromotive force *P* in series with an ammeter *O*, a controlling rheostat *RF* and a reversing switch *L*. Interposed be-

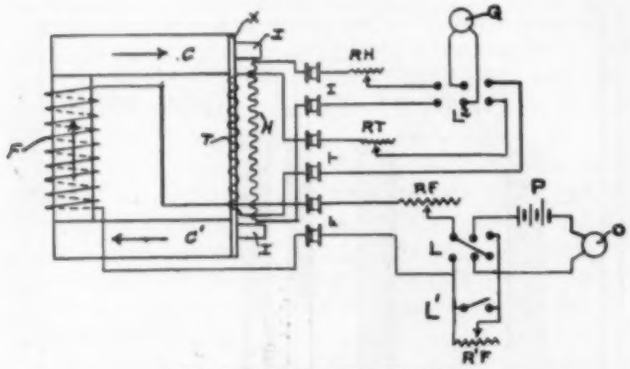


FIG. 4.—PLAN OF CIRCUITS

tween two of the points of switch *L*, as shown, is a second switch *L'* which bridges a rheostat *R'F*. The terminals *T* and *H* are connected through controlling resistances *RT* and *RH* respectively to a multipoint switch *L'* so that each of these circuits may at will be connected to an indicating instrument *Q*.

This indicating instrument *Q* is a special form of galvanometer of the D'Arsonval type which is calibrated by a mutual inductance, not shown in Fig. 4 When the galvanometer is adjusted in accordance with the constants of the coils *T* and *H*, which is brought about by manipulation of the resistances *RT* and *RH* respectively, its reading indicates directly the magnetic effects operating upon the particular circuit to which it is connected.

Basis of Operation

In the use of the permeameter a test specimen *X* is inserted within the coil *T* and clamped in place by means of the screws *D*. The test specimen should preferably be long enough to span the outer extremities of the pole faces, and may be as much longer as desired. Comparative data may however be obtained with lengths which do not actually bridge the pole faces. The screws *D* engage with the magnetic contact shoes *I* and *I'* so that, as shown diagrammatically in Fig. 4, one face of the test material *X* makes contact at each end with a polar face of the core arms *C* and *C'*, while the opposite face makes contact with *I* or *I'*. By reason of the nonmagnetic supporting blocks *a'*, *I* and *I'* make magnetic contact solely with the material under test and not with any portion of the magnetic core.

The magnetic induction in the test material *X* is determined in the usual manner from the magnitude of the impulsive throw of the galvanometer which occurs when the latter is connected to the test coil *T* and the direction of flow or magnitude of the current in the magnetizing coil is changed. That is, a quantity of electricity flows through the galvanometer which corresponds in magnitude to the change in induction in the test material. When the galvanometer is connected to the coil *H* and the current in the magnetizing coil is changed in any manner, the impulsive throw of the galvanometer indicates the change in induction in the air space encircled by the coil winding *H*. This change in induction corresponds to the change in magnetic potential existing between the ends of the test material. The average magnetic potential drop per unit length of the winding *H* is equal to the average magnetizing force to which the body *X* is subjected. Observation therefore of the throws of the galvanometer when the latter is connected in sequence to the coils *T* and *H* and the same change in current in the magnetizing coil is gone through indicates the induction and the corresponding magnetizing force.

The use of the shoes *I* and *I'*, which are of low reluctance, removes the necessity of having the ends of the coil *H* immediately in contact with the test material, which would seriously limit the practical utility of this method of measuring magnetizing force. Since the shoes are in magnetic contact with the material under test only, the magnetic potential measured is actually that operative on the specimen. Faulty contact between the test material and the magnetic core, which would cause excessive magnetomotive force drop at the polar contact faces and result in serious error in measurement if the magnetizing force were calculated from the ampere turns, knowing the constants of the magnetizing coil, which is a common method, has no appreciable effect on accuracy in the method here described. Such faulty contact may be due to the test material not being straight or having irregular or scaly surfaces. The compensating adjustments required in most permeameters are designed in large part to overcome such conditions by supplying additional magnetomotive force to offset the losses at the contact faces.

Manipulation

The test material is inserted within the coil *T* and the clamps *D* screwed up so that the material makes reasonably good contact with the polar faces of the core

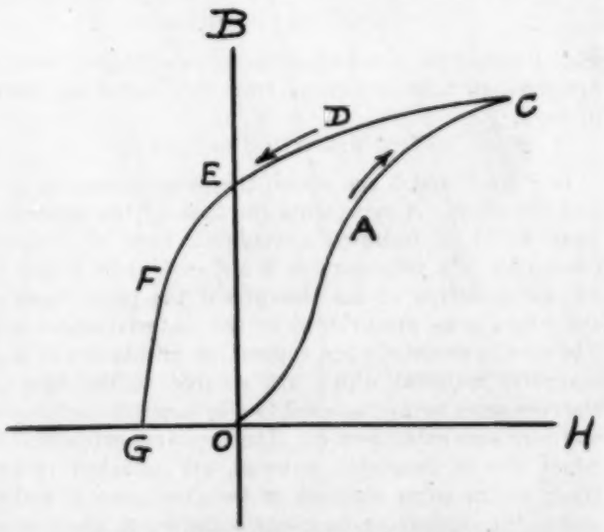


FIG. 5.—NORMAL INDUCTION CURVE

arms and with the contact shoes. The material may be in the form of a very long bar and the test confined to any region along its length.

The galvanometer is calibrated by means of a mutual inductance, and the resistances *RT* and *RH* adjusted so that when successively connected to the coils *T* and *H* in the course of a test, the readings will indicate flux density. The flux density observed when the coil *T*

is connected to the galvanometer is subject to a slight correction to obtain the actual density in the material under examination. This correction is the result of the coil *T*, which must necessarily be somewhat larger in cross-sectional area than the test material, encircling more flux than threads the material alone. The flux density threading the coil *H* indicates directly the magnetizing force.

Determination of Normal Induction

The coil *F* is energized and the material under test demagnetized by repeated reversals of a successively decreasing magnetizing current. During these reversals and throughout the normal induction test, the switch *L'* is closed so that whether switch *L* be closed to the right or left the same current flows through coil *F*. The demagnetizing operation is for the purpose of freeing the material from the effects of any previous magnetization and it is sufficient for this purpose to start the demagnetization from a current value which carries the induction beyond the point of maximum permeability, as *A*, Fig. 5. After reducing the induction to practically zero, the magnetizing current is increased to the value which will give the lowest induction desired for the test data. This current is then reversed several times to bring the material into a magnetically cyclic state.

To read the induction, the coil *T* is connected to the galvanometer by means of the switch *L'* and the impulsive throw noted when the current in the magnetizing coil is reversed in direction by means of the switch *L*. To read the corresponding magnetizing force the galvanometer is connected to the coil *H* and the throw noted when switch *L* is again reversed. Successive readings of induction and the magnetizing forces corresponding thereto may be made by increasing the current in *F*, by steps, up to the point of maximum induction desired. No further demagnetizing is required for values of induction higher than the initial one.

Determination of Hysteresis

Hysteresis determinations may be made from any value of flux density reached by the material under test. As indicated above, the hysteresis, for any given material, depends upon this maximum value of flux density. In the standard tests of materials which enter into electrical apparatus where we are directly concerned with the magnetic quality of the material, this induction is usually specified as 10,000 in the case of sheet steel, and for permanent magnet material as that induction which is reached under a magnetizing force of 200. In the investigation of materials where information as to their mechanical characteristics is sought, the maximum induction employed is that corresponding to practical saturation of the material.

In determining hysteresis, the switch *L'* is closed and the current in coil *F* increased to give the proper maximum induction. Switch *L* is then reversed several times, being finally thrown to the right, Fig. 4. The induction is then represented by the point *C*, Fig. 5. If switch *L'* is then opened, the rheostat *R'F* is then interposed in the magnetizing coil circuit, and both the induction and magnetizing force fall to the values represented by, say, the point *D*, Fig. 5. If the galvanometer is successively connected to the coils *T* and *H* while this operation is gone through, the throws of the former will indicate the changes of induction and magnetizing force resulting. Subtraction of the values represented by these changes from the values represented by the point *C* will establish the point *D*.

Except where the material under test is extremely soft, or in other words of high permeability, the determination of the point *E* is made, having closed switch *L'*, come back to the point of maximum induction and reversed several times, by opening switch *L* and observing the changes in induction threading the coils *T* and *H*

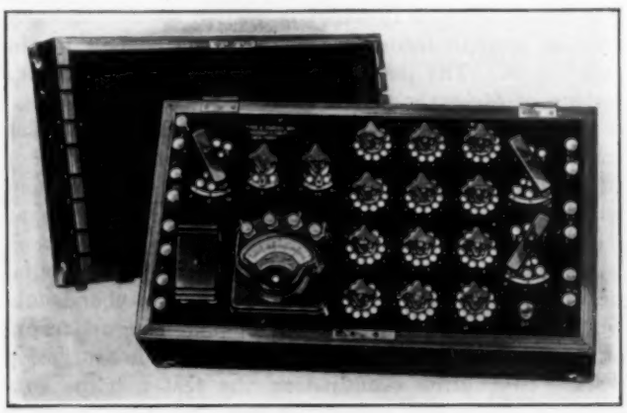


FIG. 6.—CONTROL BOX

as above. Opening the switch *L* reduces the magnetizing force to practically zero. However, the test material is still subject to a very small magnetizing force, which finds its source in the residual induction of the soft iron core of the permeameter. The amount of this magnetizing force is negligible in the testing of magnet steels and tools, but where it is necessary to take it into account establishing the point *E* requires the application of a small magnetomotive force in the reversed direction. The procedure is then the same as that for establishing the point *F*, described below, the only difference being in the amount of reversed magnetizing force applied.

To establish the point *F*, proceed as before, magnetizing the material to the point *C*, reversing switch *L* several times and finally closing it to the left, Fig. 4. Then having opened switch *L'*, throw switch *L* to the right. This reduces the magnetizing force from the value represented by the point *C* to a lower value in the reverse direction. To reduce the induction to zero, that is to establish the point *G*, start again from the maximum induction, adjusting rheostat *R'F* until the change of induction indicates that the induction has finally been reduced to zero.

In general, the determination of hysteresis in practice goes only as far as the determination of the points *E* and *G*. The ordinate *OE*, Fig. 5, represents the residual induction, or that induction which persists under zero magnetizing force after previous magnetization. The abscissa *OG* represents the coercive force, or that reversed magnetizing force which is required to reduce the residual induction to zero. These values, residual induction, designated by *Br*, and coercive force, designated by *Hc* are the two important properties with which we are concerned in the examination of steels intended

for use as permanent magnet material. These quantities are of equal importance in the testing of materials where it is desired to interpret the magnetic data in terms of structural stability.

A control box, Fig. 6, has been designed for use in connection with this permeameter which contains in compact form the switching apparatus shown diagrammatically in Fig. 5, together with the mutual inductance for calibrating the galvanometer and the adjusting resistances.

The permeameter shown in Figs. 2 and 3 is especially adapted to the measurement of the properties of materials where it is convenient to prepare samples for test. For material which is round in section special bushings may be used to insure reasonably good contact at the polar faces. The instrument may also be used in the testing of diversely shaped tools, but with some special shapes a modification of the design is called for. The control equipment external to the permeameter proper is suitable for use with any modification of the instrument which is necessary by reason of special conditions or requirements.

The test procedure outlined above under "Manipulation" is seldom gone through in its entirety and only when all of the properties of the material under examination are to be determined, as an investigative work. In routine examination the test may be confined to the determination of the induction under a given magnetizing force, or the determination of the residual induction or coercive force, or both. It will frequently be found that but a single criterion is necessary to establish the nature of the material. When either permeability or hysteresis tests are made at reasonably high values of induction, which is almost always the case, there is no necessity of initially demagnetizing the test material.

50 Church St.,
New York City.

Automatic Blow-Case Valve

AN automatic device consisting of a compound liquid check valve and air line control employed for air blowing in acid montejus has been developed by the Monarch Manufacturing Works, Inc., 3128 Emery Street, Philadelphia, Pa. Fig. 1 shows the device, which consists of two flange-like parts. The heavy dotted line indicates the bases of the ribs, the intervals between which form parts for the flow of the incharging liquid around the check and air valves. The valves sit loosely on the seat formed by the ribs. Through the lower ribs, air ports are bored.

The acid flows from the storage tank, tank car etc. through the combination check valve and air device, into the montejus. As the blow case fills with liquid, the volume occupied by the air contained becomes smaller with accompanying compression. When this counter air pressure has become equal to the liquid head, a surging escape of air takes place, which unseats the air valve and allows an influx of compressed air through the rib air ports. This pressure is sufficient to seat the valve tightly against the upper inlet *s*, shutting off the inflow of liquid and discharging the acid from the base through the open discharge line. When the charge has been blown out, the air escapes so rapidly that the fluid head pushes the valves into the lower seats, stopping the discharge of compressed air and starting a recharge of acid.

A feature of this device is the operation of the valves, which are worked in counter-current to the inflowing liquid. This is made possible because the inverted-cup-shaped check does not rest on the air port stopper, thus allowing freedom for the easy upward movement of this part when the surging effect takes place. The manufacturers make this device in several sizes using all the usual materials excepting stoneware.

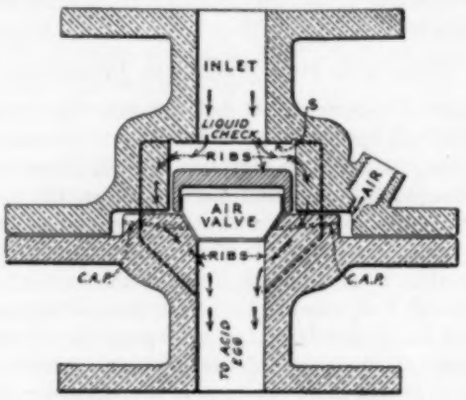


FIG. 1.—BLOW-CASE VALVE

All in Readiness for Chemical Exposition

More than 350 exhibitors have signed contracts to date for space at the Fourth National Exposition of Chemical Industries to be held in Grand Central Palace the week of September 23-30. This means that all of the floor space on the three available exposition floors of the building will be filled to capacity with the most interesting and varied displays relating to the chemical industry and its thousands of ramifications. When the public stops to consider that the wonderful drive now being made on the Western front is due in a large measure to the advances made in chemistry in this country since the beginning of the war, and that our chemical processes varying from munitions and poison gas to alloy steel are, like American fighters, superior to the German product, the importance of a great clearing house for the brains of this industry is at once apparent. That, in effect, is what the huge exposition is—a great get-together which affords the master minds an opportunity to meet in one place and exchange ideas in personal interview in a way that eliminates thousands of miles of railroad travel.

The fact that the United States Government is about to take over Grand Central Palace and convert it into a base hospital positively will not interfere with the holding of this exposition, which will terminate on September 30. In fact it is said that high officials of the Government considered this exposition such an important one that they would be loathe to interfere with its successful presentation. Arrangements have been made to remove the displays at the close of the exposition in ample time to suit the Government. The latest information regarding the building is that it will be remodeled to accommodate 3000 patients and will be ready December 1. The lease is for the period of the war and three months after.

Book Reviews

JAMES WOODHOUSE. By Provost *Edgar Fahs Smith.* 299 pages. Price $1.50. Philadelphia: The John C. Winston Company.

The chemical activities of James Woodhouse are of interest to all chemists, whether they have a taste for the history of the science and its literature or desire to confine their attention to bare practicalities. Dr. Smith has expended great efforts to convey an insight into the scientific character of this pioneer American chemical genius. His laboratory at the University of Pennsylvania was the forge where the weapons were wrought which conquered the phlogiston theories, then championed in this country by Joseph Priestley whose style of work is presented in his own writings on "Experiments and Observations on Different Kinds of Air," 1775, where he says: "More is owing to what we call chance . . . than to any proper design or preconceived theory in this business."

Woodhouse was not a chance chemist. He did not look for the proverbial "discovery by accident." He had a fair imagination but did not make Grecian use of it. He labored diligently in his laboratory. Whether he sought an economic use for persimmons or a national source of nitrates, he worked with a scientific procedure of almost modern characteristics. He was not a mere understudy of the European schools; and whatever may have been the motives of Dr. Benjamin Rush in lending his influence in having Woodhouse appointed to the chair of chemistry at Pennsylvania, the name of this successor to Franklin in the scientific circles of our first capitol will be mentioned by chemists with pride.

* * *

SULPHURIC ACID HANDBOOK. By *Thomas J. Sullivan.* Pages 240. Price $2.50. New York: McGraw-Hill Book Company, Inc.

This is the most up-to-date handbook of the numerical data on sulphuric acid. It treats of its subject from the gaging of the volume in vertical or bumped horizontal cylindrical tanks right through the laboratory gravity and temperature determinations and calculations, and finally ends with splendid data on iron and lead acid-proof pipes and fittings.

The recognized standard tables in use in the United States on the Baumè hydrometer scales and the acid gravities etc. (Ferguson and Talbot determinations) adopted by the Manufacturing Chemists' Association of the United States are given. Most of the data on the manufacture of acid, on sulphur, sulphur dioxide gas, nitric and nitrous acid, arsenic, selenium etc. are sufficiently covered for practical application in the plant. All chemists having anything to do with the mineral acids will find their requirements best taken care of by consulting this convenient handbook.

* * *

THE JOURNAL OF THE INSTITUTE OF METALS, Vol. XIX. Edited by *G. Shaw Scott, M. Sc.* 316 pages. Price 21s. net. The Institute of Metals, 36 Victoria Street, London, S. W., England.

Among the various contributions published in this volume of the well known *Journal* may be mentioned "The Constitution of the Copper Rich Aluminum-Copper Alloys" by J. Neill Greenwood, and "An Investigation on Unsound Castings of Admiralty Bronze (88:10:2): Its Cause and the Remedy" by Prof. H. C. H. Carpenter and Miss C. F. Elam. An appreciation of the importance of the papers presented at the last meeting of the Institute may be gathered from the fact that the spoken and written discussion occupies much more space than the text of the contributions. Sixty pages of closely printed abstracts of the current literature on non-ferrous metallurgy close the volume, which, needless to remark, sustains the high tone of its predecessors.

Personal

MR. H. K. BENSON has accepted a captain's commission in the Ordnance Department and has been assigned to the nitrate division for the investigation of the arc process in nitrogen fixation. Captain Benson was formerly professor of industrial chemistry and director of the Bureau of Industrial Research, University of Washington. During the past summer he made a field study of nitrogen products for the American Nitrogen Products Co., Seattle, Wash.

MR. F. W. BRUCKMILLER, formerly assistant professor of chemistry at the University of Kansas, is now chemist for Standard Oil Co. (Indiana) at Sugar Creek, Mo.

MESSRS. ALBERT BURCH and H. W. HARDINGE are in charge, respectively, of the Pacific Coast and Appalachian districts recently created by the U. S. Bureau of Mines for the purpose of making an inventory of manganese deposits and to assist in stimulating production. The country has been divided into four districts. In this same connection, G. H. CLEVENGER is stationed at Golden, Colorado, in charge of experiments in the metallurgy of manganese.

MR. LEONARD W. EGAN, formerly with the Wellman-Seaver-Morgan Co., has severed his connection with that corcern and has become associated with the Electric Furnace Company as special engineer.

DR. HARRY S. FRY, formerly associate professor of chemistry, has been appointed professor and head of the department of chemistry at the University of Cincinnati. Other appointments in this department are as follows: DR. EARL F. FARNAU, associate professor of organic chemistry, formerly assistant professor of chemistry at New York University; DR. RALPH E. OESPER, associate professor of analytical chemistry, formerly assistant professor of chemistry at Smith College; DR. CLIFFORD J. ROLLE and DR. LEONORA NEUFFER, instructors in chemistry.

MR. S. GEIJSBEEK of the Geijsbeek Engineering Company has been appointed district chief for Oregon, Washington and California for the Industrial Furnace Section, Bureau of Conservation, U. S. Fuel Administration.

MR. L. H. GOEBEL has resigned as superintendent of filtration and chief chemist of the Water Filtration Plant of the Union Stock Yard and Transit Company, Chicago, Ill., to become associated with the engineering staff of Wallace & Tiernan Company, manufacturers of chlorine control apparatus and sanitary engineering specialties.

MR. MAX K. GROSSHEIM has been put in charge of the engineering department of L. O. Koven & Brothers, Jersey City, N. J.

MR. ROBERT GEORGE HALL, formerly general manager of the River Smelting and Refining Co., St. Louis, Mo., has been appointed resident manager of the Burma Mines, Ltd., Namtu, Upper Shan States, Burma.

MR. VANCE MCCARTY, for the past twelve years manager of the Pittsburgh branch of Edw. R. Ladew Company, Inc., has been appointed general sales manager of the company, with headquarters in the New York office, 54 Franklin Street.

MR. DWIGHT D. MILLER, formerly with the engineering department of the Society for Electrical Development, New York, is now with the Electric Furnace Co. of America, Alliance, Ohio, as manager of the New York office.

MR. JOHN D. RYAN, president of the Anaconda Copper Co., presented his resignation to the Board of Directors on Sept. 3. As Director of Aircraft Production, Mr. Ryan is now Assistant Secretary of War. Mr. C. F. Kelley will succeed Mr. Ryan as president.

MR. ERNEST B. TALKER is now connected with the Inland Steel Co., Indiana Harbor, Ind., as master mechanic of the furnace plant. He was formerly with the By-Product Coke Corp., South Chicago, Ill.

Current Market Reports

The Non-Ferrous Metal Market

Monday, Sept. 9.—The metal markets are very steady. The munition consumption gradually approaches the supply, but Government regulation prevents competitive buying by outsiders.

Aluminium:—The Government prices on ingots 98 to 99 per cent Al are $660 a ton f.o.b. plant in 50-ton lots; $662 down to 15-ton lots; and $660 down to 1-ton lots, which prices will continue the remainder of the year. Prices per pound for small lots vary from 40 to 45c.; sheet aluminium, 18ga. and heavier, 42c.; powdered aluminium, 100 mesh, 70c.

Antimony:—The recent rise in antimony was but temporary, the price now being 14 to 14¼c. for duty paid spot delivery.

Chrome:—Western production is now in slight excess of demand. The nominal quotation for 40 per cent ore is $1.40 per unit, while 50 per cent ore is bringing $1.70.

Copper:—The price of $520 per ton for car load lots and 27.3c. per pound for small quantities is permanently fixed.

Copper sheets, hot rolled	lb.	$0.36	—$0.37½
Copper sheets, cold rolled	lb.	.37	—.38½
Copper bottoms	lb.	.44	—.45½
Copper rods	lb.	.36	—.37
Copper wire	lb.	.29½	—....
High brass wire	lb.	.28½	—.29½
High brass sheets	lb.	.28½	—.29½
High brass rods	lb.	.26½	—.28½
Low brass wire	lb.	.32½	—.34½
Low brass sheets	lb.	.32½	—.34½
Low brass rods	lb.	.33½	—.35½
Brazed brass tubing	lb.	.37	—.39
Brazed bronze tubing	lb.	.42½	—.44½
Seamless copper tubing	lb.	.41	—.43
Seamless bronze tubing	lb.	.45	—.46
Seamless brass tubing	lb.	.37½	—.39½
Bronze (gold) powder	lb.	1.00	—1.75

Lead:—The lead market is limited by selling restrictions. Producers must sell at a uniform and pre-arranged price. In car load lots at East St. Louis, the price is $155 per ton. In New York, all speculative and traders' lead has disappeared. The Lead Committee apportions lead at 8.05c. to legitimate consumers.

Manganese:—The scale prices on page 629 of CHEMICAL & METALLURGICAL ENGINEERING, June 15, prevail; the highest price per unit being $1.35.

Zinc:—Spelter continues to advance. East St. Louis is selling at $183 to $185 per ton in car lots; New York quotations are from 9.4 to 9.5c. per pound; sheet zinc 15c. and zinc dust (300 mesh) 16c. per pound in 1600-lb. casts.

Tin:—Outside tin prices are on the ebb, New York spot being at 80c. This seems to be due to a tendency of consumers to take the reins out of the market's hands and to proportion the available supplies; present prices being believed to be sufficient to maintain the maximum production physically possible. Babbitt metal varies between $1.00 and 65c.; solder (50-50), 73c. per pound.

Tungsten:—The western producers of Scheelite are reluctant in offering at $25.50 per unit. High grade Wolframite is bringing $25. Off-grade ores vary from $20, to $24.

Silver:—The Government price of $1.01⅛ is hoped to promote production.

OTHER METALS

Bismuth	lb.	$3.50	—$3.65
Cadmium	lb.	1.50	—....
Cobalt	lb.	2.50	—3.50
Magnesium	lb.	1.75	—2.00
Mercury	75 lb.	125.00	—....
Mercury	lb.	1.95	—....
Nickel	lb.	.40	—.43
Iridium	oz.	175.00	—....
Palladium	oz.	135.00	—....
Platinum	oz.	105.00	—....

The Iron and Steel Market

With the total steel requirements for the half year, as estimated by the War Industries Board, increased to not less than 23,000,000 net tons, the supply will reach a shorter distance down the preference list than had been expected. As a matter of fact, in the majority of cases there will be no steel at all for purposes that are not distinguished except by a place on the preference list. It may be well to explain that while shipments "on the preference list" follow shipments against priorities, the preference list itself is not confined to purposes for which priorities are not given. The preference list includes aircraft, munitions and in fact practically all the most important direct war requirements, for which priorities were for a long time granted individually by the war Industries Board, and for which "automatic priority" was provided in the regulations of last July. All priority business is represented on the preference list, but what are ordinarily classed as preference shipments are those made by virtue of the preference list and not by virtue of priorities.

Thus substantially all the steel shipped is shipped for purposes included in the preference list, but by far the major portion has the priority authority in addition. As to class D, or "permit" steel, which is steel that may be left after the preference list is taken care of, there is, practically speaking, no such thing. In every instance the steel would arise only by the making of off heats or of off material in rolling, and the percentage is very small. As a rule, apparently, mills are disposed to hold such steel on the chance of finding a priority or preference use for it, with its use as scrap as a last resort. Such use, indeed, seems to have been definitely recommended at a recent conference between the War Industries Board and representatives of the steel makers. Scrap being extremely scarce, there is an opportunity of increasing the supply of war steel by such use.

In the case of many producers it is impossible to provide any steel for plain preference purposes, the priority requirements being too extensive. There are many finishing departments that cannot go farther than to take care of all priorities of classes AA and A, with nothing left for the class B priorities, which run from 1 to 8. Steel for replacement of jobbers' stocks, as decreased by priority and preference shipments of jobbers, has B4 priority, and in the case of many mills the supply plays out in that class, the mill being able to ship some B4 steel but not all that has been scheduled. By about the end of August, practically all of the jobbers' August quotas had been scheduled by the mills, but some of the steel will not actually have been shipped by the end of this month.

PRODUCTION

Production is increasing slightly over the July-August average, which was between 40,000,000 and 41,000,000 tons a year in pig iron and about 42,000,000 tons a year in steel ingots. While the weather was hot, particularly in the first 12 days of August, the curtailment in production on account of high temperatures was less than in any previous summer, the strenuous efforts of managers, foremen and many workmen serving to obviate very largely the relaxation that usually occurs.

In the case of pig iron production there seems to be three restrictive influences—coke, labor and manganese alloys. There has been continued complaint by some furnaces of poor quality coke and there has also been some actual shortage of coke. Both conditions have been taken strongly in hand by the Fuel Administration. For instance, at a meeting in Uniontown on September 4, Warren S. Blauvelt, director of the coke division of the Fuel Administration, met about 200 operators of the general Connellsville region and made a strong plea for the shipment of good, clean coke, urging that steel made now will save human lives by shortening the war. The Railroad Administration is coöperating by endeavoring to furnish absolutely full supplies of by-product coal to the by-product coke ovens, but there is not much to be gained in this respect, seeing that the Geological Survey reports have for months past shown very nearly full supplies, losses in by-product coke output through shortage of coal not having averaged more than perhaps 2 per cent. The efforts do not stop there, however, as there is a larger field for improvement in that as by-product ovens have been completed some beehive ovens have been closed in order to divert the coal to the by-product ovens. If coal from elsewhere can be provided, the closed beehive ovens can resume operations. The seriousness of this situation was brought out early in September, when

the weekly report of coke production, for the week ended August 24, was circulated. Comparing the four weeks ended May 18 and the four weeks ended August 24, there was a decrease in the weekly production of beehive coke of 95,000 tons and an increase in the production of by-product coke of 55,000 tons, showing a net loss of 55,000 tons, this representing, of course, an entirely unsatisfactory state of affairs.

As to labor restricting the production of pig iron, the cases are largely local, chiefly in Virginia, Alabama and Tennessee districts. With respect to the interference of manganese alloys, it is believed in many quarters in the trade that too many furnaces are operatng on ferromanganese or spiegeleisen, there being about 20 altogether. It is quite clear that in the market pig iron is much scarcer than ferromanganese or spiegeleisen, and it may be that consumers have large stocks of the manganese alloys besides.

As to steel ingot production, the existing capacity under normal operating conditions could certainly be counted upon for at least 47,000,000 tons a year, whereas the highest rate of production attained has been the 43,500,000-ton rate of June, production in the past two months having been at a somewhat lower rate. On account of limited supplies of scrap and poor quality of what is available, rated outputs cannot be attained, but still it is probable that with an unlimited supply of pig iron more steel could be made.

Distribution of Steel

The War Industries Board names railroad steel as the largest single item in the present requirements, shipbuilding coming second, Army needs, including those of our allies, third, and Navy needs fourth. This of course is not a normal sequence, the high place accorded railroad steel being due to the fact that taking care of the railroads was postponed in favor of more important needs, but cannot be postponed further on account of winter impending. The railroads have been functioning wonderfully well of late compared with their partial breakdown last winter, but cannot be expected to continue doing as well when inclement weather comes.

The combination of heavy rail demands for domestic roads and heavy demands for the A. E. F., an additional 200,000 tons having been ordered for the latter a few weeks ago, rail production is now at a heavy rate, and shell steel manufacture has been largely displaced at some rail mills. At the same time the shell steel requirements have greatly increased, by reason of Marshall Foch's great offensive, and the success the smaller guns have had. A large additional amount of shell steel will therefore have to be contributed by other lines. Two wire departments, Donora and Woodlawn, are being altered for the rolling of shell rounds instead of rod billets, as one contribution. Thus the production of wire will be curtailed and it is probable that production of merchant bars, of standard pipe and of sheets and tin plates will also be curtailed.

The Chemical Market

Coal Tar Products:—The situation underwent but little change during the past two weeks, although of the important crudes benzol was in better demand and supplies are liberal. Chemical prices are inclined to a firmer tone than otherwise. The intermediates in general are in fair demand with prices having an upward tendency due to the restricted offerings.

Benzol:—A slight improvement is evident in the buying demand. Considerable interest has been shown in benzol for automobile propulsion which was created through the recent request of the Fuel Administration for the conservation of gasoline. The increase in demand however is not great enough to deplete the large quantities on the market and quotations are 23c. in spot in tank cars and 28c. spot, drums extra and returnable.

Phenol:—A quiet market prevails locally but it is said that some large exportations have been made to Japan where the material appears to be urgently needed. Supplies are plentiful and prices are 40c. export drums, but 43 to 44c. drums included are generally quoted.

Diethylaniline:—There are more offerings of this product, but buying interest is quiet, with spot material quoted at $4 f.o.b. works.

Paraphenylenediamine:—Movement is running ordinarily; however, available material is limited and dealers offer no encouragement; prices range from $4.00 to $4.50 which appears to be about the firm level.

Acetanilid:—The demand is not heavy, although for a short period the item has had some activity. Offerings of the material are held at from 68 to 70c. for the U.S.P. and the technical is quoted at 65c.

Para-amidophenol:—Trading is seemingly steady and offerings are made by large dealers at from $4.00 to $4.50 for the base material.

Dinitrophenol:—Producers are concentrating their efforts for Government purposes and supplies are insufficient for immediate requirements. No spot is available and the nominal asking price is 52c.

Aniline Oil:—Limited stocks are reported and the demand is fair. Small scattered offerings tend to keep prices at firm levels of about 30c.

Aniline Salts:—The product is reported in only fair quantities and second hands are taking advantage of the situation, obtaining a range of prices by no means low for the small amount of material on hand.

Beta Naphthol:—Both sublimed and technical grades are in reasonable demand, but the production is not in proportion to requirements. Quotations remain at the firm level of from 80 to 90c. for the sublime and 60c. for the technical material.

Benzidine Base:—Offerings are liberal but the demand is only routine, with principal purchases being made for export purposes. Prices are quotable unchanged at $1.75.

Heavy Chemicals:—Trading generally has been fairly satisfactory, with the volume of business apparently on the increase. Prices have had an upward tendency with the exception of some items which are easier and not so firm in demand.

Soda Ash:—Consumption requirements are strong and offerings obtainable are being held at strong levels. Considerable speculation is rife and the price asked at New York is $2.50. Double bags are quoted at works at about $3.10 with barrels named at prices from $2.80 to $3.00. Dense ash from works is reported to be sold as high as $4 double bags, with other quarters quoting $3.70 double bags and barrels.

Salt Cake:—A lack of consuming interest has resulted with practically no change of position in this market. The general run of selling values is from $22 to $25 bulk Northern points.

Caustic Soda:—The market was more active during the past two weeks with recent sales at 4c. dock and warehouse. These prices, however, are not considered the market. The Government requirements are becoming more imperative and are now taking about one-quarter of the production. The Government has notified producers that, beginning November 1, their needs will be greater. Therefore, manufacturers have in turn notified firms holding contracts that in view of the priority of Government requirements, deliveries will be curtailed in proportion to the amount required by the Government.

Yellow Prussiate of Soda:—The market has not been marked with much change, but lack of demand is evident with regular traders quoting prices from 90c. to $1.00.

Bichromate of Soda:—The situation has been somewhat easier with some business passing at 24c., but no interest is shown in the product at a higher figure.

Permanganate of Soda:—Despite the fact that potassium salt has declined in price to a marked extent, manufacturers of the soda solution continue to quote a price of $3 per gallon.

Copper Sulphate:—Demand has been reasonably active of late with producers having the situation well in hand. Sales of spot have occurred at 9c.

Sulphate of Alumina:—A strong situation prevails in this market and consumers who find it necessary to cover are seemingly up against a rising market. Odd lots appear of the iron-free, having sold lately at from 4¼ to 4½c.

General Chemicals

WHOLESALE PRICES IN NEW YORK MARKET, SEPT. 9 1918

Acetic anhydride	lb.	1.90 —	2.00
Acetone,	lb.	.25½ —	.25½
Acid, acetic, 28 per cent	cwt.	5.96 —	6.11
Acetic, 56 per cent	cwt.	10.76 —	10.87
Acetic, glacial, 99½ per cent, carboys	cwt.	19.50 —	19.70
Boric, crystals	lb.	.13½ —	.15
Citric, crystals	lb.	.80 —	.82
Hydrochloric, C. P	lb.	Nominal	
Hydrofluoric, 30 per cent in barrels	lb.	.06 —	.06½
Lactic, 44 per cent	lb.	.15 —	.16
Lactic, 22 per cent	lb.	.06 —	.07
Molybdic, C. P	lb.	6.90 —	7.40
Nitric, 36 deg	lb.	Nominal	
Nitric, 42 deg	lb.	.08½ —	.10
Oxalic, crystals	lb.	.42 —	.44
Phosphoric, 47-50 per cent paste	lb.	.07½ —	.09
Phosphoric, ref. 50 per cent	lb.	.35 —	.40
Picric	lb.	Nominal	
Pyrogallic, resublimed	lb.	3.25 —	3.50
Sulphuric, 60 deg	ton	18.00 —	....
Sulphuric, 66 deg	ton	28.00 —	....
Sulphuric, oleum (Fuming), tank cars	ton	32.00 —	[illegible]
Tannic, U. S. P., bulk	lb.	1.40 —	1.50
Tartaric, crystals	lb.	.82 —	.83
Tungstic, per lb. of W	lb.	1.70 —	1.75
Alcohol, sugar cane, 188 proof	gal.	4.90 —	4.95
Alcohol, wood, 95 per cent	gal.	.91½ —	.92
Alcohol, denatured, 180 proof	gal.	.68 —	.69
Alum, ammonia lump	lb.	.05½ —	.05½
Alum, chrome ammonium	lb.	.18 —	.19
Alum, chrome potassium	lb.	.20½ —	.21
Alum, chrome sodium	lb.	.12½ —	.13
Alum, potash lump	lb.	.09½ —	.10
Aluminium sulphate, technical	lb.	.02 —	.02½
Aluminium sulphate, iron free	lb.	.03½ —	.04
Ammonia aqua, 26 deg., carboys	lb.	.08½ —	.16
Ammonia, anhydrous	lb.	Nominal	
Ammonium carbonate	lb.	.13 —	.14
Ammonium nitrate	lb.	(Fixed Price)	.15
Ammonium, sulphate domestic	lb.	.07½ —	.08
Amyl acetate	gal.	5.30 —	5.35
Arsenic, white	lb.	.09½ —	.12
Arsenic, red	lb.	.65 —	.70
Barium carbonate, 99 per cent	ton	80.00 —	90.00
Barium carbonate, 97-98 per cent	ton	65.00 —	67.00
Barium chloride	ton	65.00 —	70.00
Barium sulphate (Blanc Fixe, Dry)	lb.	.05½ —	.06
Barium nitrate	lb.	.12 —	.14
Barium peroxide, basis 70 per cent	lb.	.30 —	.32
Bleaching powder, 35 per cent chlorine	lb.	.03½ —	.04
Borax, crystals, sacks	lb.	.07½ —	.10½
Brimstone, crude	ton	Nominal	
Bromine, technical	lb.	.75 —	....
Calcium, acetate, crude	lb.	.04 —	.05
Calcium, carbide	lb.	.19 —	.20
Calcium chloride, 70-75 per cent, fused, lump	ton	22.00 —	24.00
Calcium peroxide	lb.	1.50 —	1.70
Calcium phosphate	lb.	.22 —	.23
Calcium sulphate 98-99 per cent	lb.	.09 —	.09½
Carbon bisulphide	lb.	.08 —	.09
Carbon tetrachloride, drums	lb.	Nominal	
Carbonyl chloride (phosgene)	lb.	1.10 —	1.50
Caustic potash, 88-92 per cent	lb.	.60 —	.75
Caustic soda, 76 per cent	100 lb.	4.15 —	4.50
Chlorine, liquid (Government Purchase)	lb.	(Fixed Price)	.07½
Cobalt oxide	lb.	1.60 —	1.65
Copperas	lb.	.02 —	.02½
Copper carbonate	lb.	.30 —	.31
Copper cyanide	lb.	.75 —	.78
Copper sulphate, 99 per cent, large crystals	lb.	.09½ —	.09½
Cream of tartar, crystals	lb.	.76 —	.80
Epsom salt, bags, U.S.P	100 lb.	3.62½ —	3.90
Formaldehyde, 40 per cent	lb.	.16½ —	....
Glauber's salt	lb.	.02½ —	.03
Glycerine, bulk, C. P	lb.	.63 —	.65
Iodine, resublimed	lb.	4.25 —	4.30
Iron oxide	lb.	.13 —	.15
Lead acetate, white crystals	lb.	.17 —	.17½
Lead arsenate (Paste)	lb.	.15 —	.18
Lead nitrate	lb.	Nominal	
Litharge, American	lb.	.12 —	.14
Lithium carbonate	lb.	1.50 —	2.05
Magnesium carbonate, technical	lb.	.16 —	.17
Nickel salt, single	lb.	.14 —	.15
Nickel salt, double	lb.	.12 —	.13
Phosgene, (see Carbonyl chloride)	lb.	1.10 —	1.50
Phosphorus, red	lb.	1.00 —	1.15
Phosphorus, yellow	lb.	1.08 —	1.15
Potassium bichromate	lb.	.45 —	.46
Potassium bromide granular	lb.	1.25 —	1.26
Potassium carbonate calcined, 85-90 per cent	lb.	.38 —	.40
Potassium chlorate, crystals	lb.	.40 —	.41
Potassium cyanide, 98-99 per cent	lb.	.60 —	.70
Potassium iodide	lb.	3.75 —	3.80
Potassium muriate 80-85 p. c. basis of 80 p. c.	ton	300.00 —	350.00
Potassium nitrate	lb.	.27 —	.31
Potassium permanganate U. S. P	lb.	1.30 —	1.75
Potassium prussiate, red	lb.	2.30 —	2.50
Potassium prussiate, yellow	lb.	1.00 —	1.10
Potassium sulphate, 90-95 p. c. basis 90 p. c.	ton	Nominal	
Rochelle salts	lb.	.47 —	.48
Salammoniac, gray gran	lb.	Nominal	
Salammoniac, white gran	lb.	.19 —	.20
Sal soda	100 lb.	1.40 —	1.65
Salt cake	ton	22.50 —	25.00
Silver cyanide, based on market price of silver	oz.	.... —	....
Silver nitrate	oz.	.63½ —	.64
Soda ash, 58 per cent, light, flat (bags)	100 lb.	2.45 —	2.50
Soda ash, 58 per cent, dense, flat	100 lb.	3.75 —	3.80
Sodium acetate	lb.	Nominal	
Sodium bicarbonate, domestic	lb.	2.75 —	3.00
Sodium bicarbonate, English	lb.	.... —	....
Sodium bichromate	lb.	.23½ —	.26
Sodium bisulphite, powd	lb.	.12 —	.14
Sodium chlorate	lb.	.25 —	.25½
Sodium cyanide	lb.	.40 —	.42
Sodium fluoride, commercial	lb.	.17 —	.18
Sodium hyposulphite	lb.	3.00 —	4.00
Sodium molybdate, per lb. of Mo	lb.	2.50 —	....
Sodium nitrate, 95 per cent	100 lb.	4.12 —	5.00
Sodium nitrite	lb.	.27 —	.30
Sodium peroxide	lb.	.35 —	.45
Sodium phosphate	lb.	.04 —	.04½
Sodium prussiate, yellow	lb.	.41 —	.45
Sodium silicate, liquid (60 deg.)	lb.	.02½ —	.03½
Sodium sulphide, 30 per cent, crystals	lb.	.06 —	.07
Sodium sulphide, 60 per cent, fused	100 lb.	9.00 —	10.00
Sodium sulphite	lb.	.05½ —	.06
Strontium nitrate	lb.	.25 —	.30
Sulphur chloride, drums	lb.	.07½ —	.09
Sulphur dioxide, liquid, in cylinders	lb.	.15 —	.40
Sulphur, flowers, sublimed	100 lb.	4.35 —	4.50
Sulphur, roll	100 lb.	3.70 —	3.85
Sulphur, crude	ton	65.00 —	70.00
Tin bichloride, 50 deg	lb.	.28 —	.29
Tin oxide	lb.	Nominal	
Zinc carbonate	lb.	.18 —	.20
Zinc chloride	lb.	.15 —	.15½
Zinc cyanide	lb.	Nominal	
Zinc dust, 350 mesh	lb.	.13½ —	.14
Zinc oxide, American process XX	lb.	.12½ —	.14
Zinc sulphate	lb.	.04½ —	.06½

Coal Tar Products (Crude)

Benzol, pure, water white	gal.	.23 —	.28
Benzol, 90 per cent	gal.	.25 —	....
Toluol, in tank cars	gal.	(Fixed Price)	1.50
Toluol, for non-military use, in drums	gal.	(Fixed Price)	1.55
Xylol, pure, water white	gal.	.45 —	.55
Solvent naphtha, water white	gal.	.18 —	.25
Solvent naphtha, crude, heavy	gal.	.12 —	.15
Creosote oil, 25 per cent	gal.	.45 —	.55
Dip oil, 20 per cent	gal.	.30 —	.32
Pitch, various grades	ton	8.00 —	20.00
Carbolic acid, crude, 95-97 per cent	lb.	1.05 —	1.10
Carbolic acid, crude, 50 per cent	lb.	.60 —	.65
Carbolic acid, crude, 25 per cent	lb.	.35 —	.38
Cresol, U. S. P	lb.	.19 —	.20

Intermediates, Etc.

Alpha naphthol, crude	lb.	1.00 —	1.10
Alpha naphthol, refined	lb.	1.50 —	1.60
Alpha naphthylamine	lb.	.60 —	.62
Aniline oil, drums extra	lb.	.28 —	.30
Aniline salts	lb.	.44 —	.45
Anthracene, 80 per cent	lb.	Nominal	
Benzaldehyde (f.f.c.)	lb.	3.60 —	4.00
Benzidine, base	lb.	1.75 —	1.85
Benzidine, sulphate	lb.	1.40 —	1.45
Benzoic acid U. S. P	lb.	2.65 —	2.85
Benzoate of Soda, U. S. P	lb.	2.65 —	2.85
Benzyl chloride	lb.	2.45 —	2.56
Beta naphthol benzoate	lb.	10.00 —	12.00
Beta naphthol, sublimed	lb.	.85 —	.90
Beta naphthylamine, sublimed	lb.	2.65 —	....
Dichlor benzol	lb.	.15 —	.20
Diethylaniline	lb.	4.00 —	4.50
Dinitro benzol	lb.	.36 —	.38
Dinitrochlorbenzol	lb.	.40 —	.45
Dinitronaphthaline	lb.	.55 —	.60
Dinitrotoluol	lb.	.65 —	.75
Dinitrophenol	lb.	.55 —	.60
Dimethylaniline	lb.	.74 —	.76
Diphenylamine	lb.	1.00 —	1.10
H-acid	lb.	3.00 —	3.40
Metaphenylenediamine	lb.	1.85 —	2.05
Monochlorbenzol	lb.	.17 —	.20
Naphthalene, flake	lb.	.09 —	.09½
Naphthalene, balls	lb.	.11 —	.12
Naphthionic acid, crude	lb.	1.20 —	1.30
Naphthylamin-di sulphonic acid	lb.	1.00 —	1.10
Nitro naphthaline	lb.	.45 —	.50
Nitro toluol	lb.	.55 —	.60
Ortho-amidophenol	lb.	.... —	....
Ortho-dichlor-benzol	lb.	.15 —	.20
Ortho-toluidine	lb.	.95 —	1.10
Ortho-nitro-toluol	lb.	.75 —	.85
Para-amidophenol, base	lb.	4.00 —	4.50
Para-amido-phenol, H. Ch	lb.	4.25 —	5.00
Para-dichlor-benzol	lb.	.15 —	.20
Paranitraniline	lb.	1.80 —	2.00
Para-nitro-toluol	lb.	1.50 —	1.60
Paraphenylenediamine	lb.	3.75 —	4.00
Para toluidine	lb.	2.00 —	2.25
Phthalic acid anhydride	lb.	4.00 —	4.50
Phenol, U. S. P	lb.	.40 —	.45
Resorcin, technical	lb.	5.50 —	7.00
Resorcin, pure	lb.	8.00 —	9.00
S-licylic acid	lb.	.85 —	.95
Salol	lb.	1.50 —	2.00
Sulphanilic acid, crude	lb.	.32 —	.34
Tolidin	lb.	2.50 —	3.00
Toluidine-mixture	lb.	.85 —	.90

Petroleum Oils

Crude (at the Wells)

Pennsylvania	bbl.	4.00 —	....
Corning, Ohio	bbl.	2.85 —	....
Somerset, Ky	bbl.	2.60 —	....
Wooster, Ohio	bbl.	2.68 —	....
Indiana	bbl.	2.28 —	....
Illinois	bbl.	2.42 —	....
Oklahoma and Kansas	bbl.	2.25 —	....
Caddo, La., light	bbl.	2.25 —	....
Corsicana, Tex., light	bbl.	2.25 —	....
California	bbl.	1.24 —	1.57
Gulf Coast	bbl.	1.35 —	....
Mexican	bbl.	1.90 —	....

Fuel Oil

New York	gal.	.15 —	....
Philadelphia	gal.	.10½ —	....
Baltimore	gal.	.07½ —	.15½c
Pittsburgh	gal.	.07½ —	.10
Texas	bbl.	1.85 —	2.35
Los Angeles	bbl.	1.65 —	....

Gasoline (Wholesale)

New York	gal.	.24½	—	.....
Gas machine	gal.	.41½	—	.....
72-76 degrees	gal.	.33½	—	.39½
70-72 degrees	gal.	.37½	—	.....
67-70 degrees	gal.	.30½	—	.36½
Pittsburgh	gal.	.25½	—	.....
Chicago	gal.	.22½	—	.23
Oklahoma	gal.	.21½	—	.....
San Francisco	gal.	.20½	—	.....

Paraffine Waxes

Crude, 103 to 105 deg. m.pt	lb.	.08½	—	.09
Crude, 118 to 120 deg. m.pt	lb.	.09½	—	.10
Crude, 124 to 126 deg. m.pt	lb.	.10	—	.....
Refined, 120 deg. m.pt	lb.	.13½	—	.....
Refined, 128 deg. m.pt	lb.	.14	—	.....
Refined, 135 deg. m.pt	lb.	.16	—	.16½
Ozokerite, brown	lb.	.75	—	.....
Ozokerite, green	lb.	.85	—	.....

Lubricants

Black, reduced, 29 gravity, 25-30 cold test	gal.	.24	—	.25
Cylinder, light	gal.	.45	—	.50
Cylinder, dark	gal.	.39	—	.41
Paraffine, high viscosity	gal.	.40	—	.41
Paraffine, .903 sp. gr	gal.	.36	—	.38
Paraffine, .885 sp. gr	gal.	.26	—	.28

Flotation Oils

(Prices at New York unless otherwise stated)

Pine oil, crude, f. o. b. Florida	gal.	.44	—	.....
Pine oil, steam-distilled, sp. gr. 0.925-0.940	gal.	.58	—	.60
Pine oil, destructively distilled	gal.	.58	—	.60
Pine-tar oil, sp. gr., 1.02 -1.035	gal.	.35	—	.....
Pine-tar oil, double refined, sp. gr. 0.965-0.990	gal.	.42	—	.....
Pine-tar oil, ref., light, sp.gr. 0.950, tank cars, f.o.b. works	gal.	.37	—	.....
Pine-tar oil, ref., heavy, sp.gr. 1.025, tank cars, f.o.b. works	gal.	.28	—	.....
Pine-tar oil, ref., thin, sp. gr. 1.060-1.080	gal.	.32	—	.....
Turpentine, crude, sp. gr. 0.870-0.900	gal.	.45	—	.....
Hardwood oil, f. o. b. Michigan, sp. gr. 0.960-0.990	gal.	.23	—	.....
Hardwood oil, f. o. b. Michigan, sp. gr. 1.06-1.08	gal.	.23	—	.....
Wood creosote, ref. f. o. b. Florida	gal.	.31	—	.....

Naval Stores

Rosin A-E barrel	280 lb.	13.25	—	13.50
Rosin F-I	280 lb.	13.60	—	14.00
Rosin K-N	280 lb.	15.00	—	15.40
Rosin WG-W	280 lb.	15.50	—	15.75
Spirits of turpentine	gal.	.66½	—	.67
Wood turpentine, steam distilled	gal.	.63	—	.....
Wood turpentine, destructively distilled	gal.	.58	—	.....
Pitch	bbl. 200 lb.	7.50	—	.....
Tar, kiln dried	280 lb.	12.50	—	.....
Retort tar	280 lb.	13.50	—	.....
Rosin oil, first run	gal.	.69	—	.....
Second run	gal.	.72	—	.....
Third run	gal.	.75	—	.....
Fourth run	gal.	.85	—	.....

Vegetable Oils

Castor oil	lb.	.28½	—	.30
China wood oil	lb.	.29	—	.29½
Cocoanut oil	lb.	.17	—	.21
Corn oil	lb.	.18	—	.....
Cottonseed oil, crude	lb.	.20	—	.22
Linseed oil, raw, cars	gal.	1.88	—	1.90
Olive oil	gal.	4.25	—	4.50
Peanut oil, crude	lb.	.18	—	.22
Soya bean oil, Manchuria	lb.	.16	—	.18

Glues

Extra white	lb.	.36	—	.45
Cabinet	lb.	.31	—	.40
Brown foot stock	lb.	.18	—	.22
Fish glue, 50-gal. barrels	gal.	1.00	—	1.80

Miscellaneous Materials

Barytes, floated, white, foreign	ton	38.00	—	42.00
Barytes, floated, white, domestic	ton	25.00	—	36.00
Beeswax, white, pure	lb.	.38	—	.43
Beeswax, unbleached	lb.	.43	—	.46
Blanc fixe	lb.	.05½	—	.....
Casein	lb.	.17½	—	.28
Ceylon graphite	lb.	.07½	—	.25
Chalk, light, precipitated, English	lb.	.04½	—	.06
China clay, imported, lump	ton	20.00	—	40.00
China clay, domestic, lump	ton	15.00	—	22.50
Feldspar	ton	8.00	—	12.00
Fluorspar, gravel, f. o. b. mines	ton	60.00	—	.....
Fluorspar, washed, powdered	ton	90.00	—	.....
Fuller's earth, powdered	100 lb.	1.50	—	2.00
Japan wax	lb.	.24½	—	.25
Mexican graphite	ton	75.00	—	.....
Madagascar graphite	lb.	.10	—	.15
Orange shellac	lb.	.75	—	.80
Pumice stone	lb.	.04	—	.08
Red lead, dry, carloads	100 lb.	11.84	—	.....
Soapstone	ton	15.00	—	25.00
Stearic acid, 120 deg. m.pt	lb.	.13½	—	.....
Stearic acid, 140 deg. m.pt	lb.	.19	—	.....
Talc, American, white	ton	20.00	—	40.00
White lead, dry	lb.	.09½	—	.10½

Refractories, Etc.

(F. O. B. Works)

Chrome brick	net ton	175.00	—	.....
Chrome cement	net ton	75.00	—	.....
Clay brick, 1st quality fireclay	per 1000	50.00	—	55.00
Clay brick, second quality	per 1000	35.00	—	40.00
Magnesite, raw	ton	30.00	—	35.00
Magnesite, calcined, powdered	ton	50.00	—	65.00
Magnesite, dead burned	net ton	50.00	—	60.00
Magnesia brick, 9x4½x2½	net ton	110.00	—	125.00
Silica brick	per 1000	50.00	—	60.00

Ferroalloys

Ferrocarbontitanium, 15-18 per cent, carloads, f. o. b. Niagara Falls, N. Y	ton	200.00	—	250.00
Ferrocerium	lb.	15.00	—	30.00
Ferrochromium, per lb. of Cr	lb.	.30	—	.40
Ferromanganese, domestic, 70 per cent basis	ton	250.00	—	.....
Ferromanganese, English	ton	325.00	—	.....
Spiegeleisen (16-18%)	ton	75.00	—	.....
Ferromolybdenum, per lb. of Mo	lb.	4.00	—	4.50
Ferrosilicon, 75 per cent, f. o. b., N. Y	ton	.....	—	.....
Ferrosilicon, 50 per cent, carloads, del., Pittsburgh	ton	180.00	—	190.00
Ferrosilicon, 50 per cent, contract	ton	160.00	—	170.00
Ferrotungsten, 75-85 per cent, f. o. b., Pittsburgh	lb.	2.35	—	2.40
Ferrouranium, f.o. b. works, per lb. of U	lb.	7.50	—	.....
Ferrovanadium, f. o. b. works	lb.	....	—	.....

Ores and Semi-finished Products

		Nominal		
Antimony ore, per unit				
Chrome ore, 45 per cent minimum, f.o.b. Cal. per unit	ton	1.50	—	1.55
Chrome ore, 43 per cent and over, New York, per unit	ton	1.40	—	....
Manganese ore, 48 per cent and over, per unit	ton	1.20	—	.....
Manganese ore, chemical	ton	80.00	—	100.00
Molybdenite, per lb. of MoS_2	lb.	1.25	—	.....
Tungsten, Scheelite, per unit of WO_3	ton	25.50	—	.....
Tungsten, Wolframite, per unit of WO_3	ton	24.00	—	.....
Uranium oxide, 96%	lb.	3.25	—	3.60
Vanadium pentoxide, 99%	lb.	10.50	—	.....
Pyrites, foreign	unit	.17	—	.17
Pyrites, domestic	unit	.28	—	.30½

Plant Supplies

BUILDING MATERIALS

Common clay brick	M	13.00	—	14.00
Hollow tile, 4 x 12 x 12	M	60.00	—	.....
Hollow tile, 12 x 12 x 12	M	170.00	—	.....
Lime	ton	16.50		
Portland cement	bbl.	2.59		
Single glass (82-lb.), 10 x 26-16 x 24		21.00	—	27.00
Double glass (164 lb.), 10 x 26-16 x 29		31.00	—	39.00
Yellow pine lumber	M	39.00	—	45.00
Fir lumber	M	38.00	—	53.00
Hemlock	M	24.50	—	40.00
Tarred felt (14-lb.-sq.)	ton	64.00		
Roofing pitch	ton	14.00	—	22.00
Asphalt coated roofing (35-55-lb. sq.)	sq.	1.30	—	2.50
State surfaced asphalt shingles	sq.	5.25	—	5.50
Corrugated galvanized iron	ton	109.00	—	127.00
Putty	100 lb.	6.25	—	.....
Red oxide (Ppte, Copperas)	100 lb.	15.00	—	20.00
Native red oxide	100 lb.	3.25	—	8.00
Red metallic paint	100 lb.	1.20	—	1.50
White lead in oil	100 lb.	13.50	—	11.42
Red lead in oil	100 lb.	14.00	—	11.84
Zinc oxide (dry)	100 lb.	13.00	—	14.50
Zinc oxide—leaded	100 lb.	9.00	—	10.00
Yellow ochre	100 lb.	1.50	—	10.00
Ultra marine blue	100 lb.	14.00	—	50.00
Prussian blue	100 lb.	135.00	—	150.00
Chrome green	100 lb.	40.00	—	70.00
Paris green	100 lb.	43.00	—	49.00
Mineral black	100 lb.	1.75	—	2.25
Powdered bone black	100 lb.	5.50	—	12.00
Lampblack	100 lb.	15.00	—	45.00
Gas carbon	100 lb.	16.00	—	25.00
Mexican petroleum pitch	100 lb.	1.00	—	2.00
Gilsonite	100 lb.	2.00	—	2.50
Coal tar pitch	100 lb.	.40	—	1.00

STRUCTURAL IRON

Blue annealed sheet iron	ton	84.00	—	89.00
Black sheet iron	ton	96.00	—	104.00
Galvanized iron	ton	105.00	—	170.00
Tern plate, 8-lb. coating	ton	150.00	—	.....
Tern plate, 15-lb. coating	ton	177.50	—	.....
Tern plate, 25-lb. coating	ton	200.00	—	.....
Tern plate, 40-lb. coating	ton	240.00	—	.....
Tin plate, prime	ton	155.00	—	.....
Tank plates	ton	65.00	—	70.00
Beams, channels, angles, T's, Z's	ton	60.00	—	65.00
Rivets	ton	88.00	—	92.00
Steel pins, ¾ to 3-inch	ton	51.00	—	.....
Bar iron and steel	ton	60.00	—	70.00
Chain (¾ inch proof coil)	ton	150.00	—	.....
Nails, bolts, nuts, washers	ton	70.00	—	80.00
Tool steels, special alloys	ton	300.00	—	500.00
Bessemer pig iron	ton	37.25	—	.....
Bessemer steel	ton	47.50	—	.....
No. 2 foundry	ton	33.50	—	.....
Steel billets (4 x 4)	ton	47.50	—	.....

POWER HOUSE SUPPLIES

Steam packing, rubber duck	lb.	.99	—	1.10
Asbestos, high pressure	lb.	1.76	—	.....
Asbestos, wired	lb.	1.30	—	.....
Asbestos, graphited braid	lb.	1.21	—	.....
Asbestos, wick	lb.	.75	—	.....
Rubber, sheet	lb.	.66	—	.....
Cup grease	lb.	.07	—	.....
Transmission grease	lb.	.07	—	.....
Axle grease	lb.	.04½	—	.....
Gear grease	lb.	.04½	—	.....
Cotton waste	lb.	.08½	—	.13
Hose, underwriters, 2½ in.	ft.	.75	—	.....
Hose, air, ¾ in.	ft.	.30	—	.60

INDUSTRIAL NEWS

Plant Construction—Catalogs—New Publications

Construction and Operation

Alabama

BIRMINGHAM.—The Magic City Cotton Oil Co., 40th St. and 12th Ave., North, will rebuild its plant recently destroyed by fire entailing a loss of $100,000.

SELMA.—A. G. Kahn Brick Co., will rebuild its plant recently destroyed by fire entailing a loss of $15,000.

SHEFFIELD.—The North Alabama Rolling Mill Co., will expend $300,000 to remodel and enlarge its plant. The company manufactures steel from waste or scrap. This project will be financed by the War Industries Board.

Arkansas

ANDERSON.—Glenn L. Brunner, will build a 40-ton log washer plant for concentration of manganese ore at his mine here, and is in the market for steam shovel, engine, boilers, belts, lumber, roofing, concrete, conveyors, scales, ore cars, wagons for hard ore, jig, pumps, piping and mill hardware. Estimated cost, $25,000. E. Berry, superintendent.

BATESVILLE.—The Poke Southern Arkansas Mining Co., will build a 50-ton log washer plant and is in the market for log washer, mill belts, roofing, engine, pump, piping, mill hardware and concrete. Estimated cost, $25,000.

California

KINGSBURG.—The city has awarded the contract for the construction of a sewage disposal system, including Imhoff tank, to Frederickson & Sharmon, 2823 Washington St., Fresno. Estimated cost $27,102.

LOS ANGELES.—The Thos. H. Ince Moving Picture Co., Hollywood, has awarded the contract for the construction of a reinforced concrete and steel motion picture studio, to include a laboratory, on Washington Boulevard and Sherman Way, to the Milwaukee Building Co., 1006 Pabst Building, Milwaukee, Wisconsin. Estimated cost, $150,000.

PASADENA.—The city commissioners of Pasadena, South Pasadena and Alhambra, have awarded the contract for the construction of an experimental sewage disposal plant using the Trent process to L. C. Trent Co., Pasadena. Estimated cost, $7000.

Connecticut

STAMFORD.—Baer Brothers, 700 Canal St., will build two factories, one on Canal St., and one on Fairfield Ave. for the manufacture of bronze powder. Estimated cost, $375,000. A. Freeman, 29 West 34th St., New York City, architect.

WATERBURY.—The Chase Metal Co., Waterville St., will build a 1-story, 40 x 320 ft., brass mill on Thomaston Ave. Estimated cost, $40,000.

Florida

FORT MYERS.—The Ocean Leather Co., 82 Beaver St., New York City, will build a plant for the manufacture of fertilizer and smoke and cure fish. Estimated cost, $30,000.

PENSACOLA.—The Bureau of Yards and Docks, Navy Department, Wash., D. C., will build a photo-laboratory, and oil reclaiming building. Estimated cost, $620,000.

Georgia

ATTAPULGUS.—The Lester Clay Co. will rebuild its fuller's earth plant recently destroyed by fire, entailing a loss of $100,000.

Illinois

CHICAGO.—The Amalgamated Machine Corp., Racine and 37th Sts., will build a 1-story, concrete and steel plant for the manufacture of large gun boring machines. Estimated cost, $500,000.

GREAT LAKES.—The Bureau of Yards and Docks, Navy Department, Wash., D. C., received low bid for addition to disposal plant from the Embankment Co., Joliet, Ill. Estimated cost, $31,420.

MADISON.—The Barker Asphalt Co. has awarded the contract for the construction of a 1-story, 100 x 160 ft. concrete, brick and steel factory, to the Austin Co., 16112 Euclid Ave., Cleveland. Estimated cost, $50,000.

Iowa

MARSHALLTOWN.—The Prier Brass Manufacturing Co., c/o W. H. Prier, will build a 1-story, 60 x 160 ft., brick foundry.

Kansas

BAXTER SPRINGS.—The Buck Shot Mining Co., Miami, Okla., will remove its 250-ton concentration plant from Joplin, Mo., and remodel same. It is in the market for sludge and slime tables, belts, mill hardware, roofing, conveyors, etc. Estimated cost, $36,000.

BAXTER SPRINGS.—The Lucky Girl Mining Co., Carthage, Mo., will build a 300-ton concentration plant and is in the market for sludge and slime tables, ore bins, ore cars, ore cans, concrete, lumber, composition, roofing, belts, air compressors, drills, pipe, cables, engine, boilers, conveyors and mill hardware. Estimated cost, $65,000. Miss Emma Knell, secretary.

BAXTER SPRINGS.—The Omaha Lead and Zinc Co., Joplin, Mo., will build a 250-ton concentration plant and is in the market for sludge, slime tables, engine, boilers, crushers, conveyors, mill hardware, air compressors, etc. Estimated cost, $65,000. T. M. Chenowith, superintendent.

BAXTER SPRINGS.—The Mississippi Queen Mining Co. will build a 250-ton concentration plant and is in the market for sludge and slime tables, belts, lumber, roofing, crushers, engine, boilers, air compressors, mill hardware, conveyors, drills, etc. Estimated cost, $65,000. W. H. Berry, superintendent.

TREESE.—The Montreal Chuff Mining Co. will build a 250-ton concentration plant on the state line and is in the market for crushers, belts, wire cables, concrete, wheels, mill hardware, engine, boilers, roofing, air compressors, pipes, pumps, drills, etc. Estimated cost, $65,000. C. F. Dyke, superintendent.

Louisiana

NEW ORLEANS.—The Bureau of Yards and Docks, Navy Department, Wash., D. C., will build a shell house. Estimated cost. $40,000.

Maryland

HYATTSTOWN.—The Hyattstown Roller Mills will rebuild its plant recently destroyed by fire, entailing a loss of $12,000. Mortier and Luhn, operators.

Massachusetts

SPRINGFIELD.—The Hampden Paint & Chemical Co., 317 Main St., has awarded the contract for the construction of a factory addition to the Casper Ranger Construction Co., 20 Bond St., Holyoke. Estimated cost, $5000.

Michigan

DETROIT.—The General Aluminum & Brass Manufacturing Co., Boulevard and Aubion Sts., will build new units to its plant to include a 2-story, 100 x 100 ft., aluminum foundry, with coke covers, two brass foundries, one 40 x 100 ft., to be equipped with sand bins and simplex and coke furnaces, the other, 60 x 180 ft., and a 3-story, 60 x 140 ft. machine shop. Government orders have made this addition necessary.

GRAND RAPIDS.—The Semet-Solvay Co., Milton Ave., Syracuse, N. Y., has awarded the contract for the construction of a 1- and 2-story, reinforced concrete, brick and steel T.N.T. plant, covering 500,000 sq.ft., floor space, to Stone & Webster Co., 147 Milk St., Boston, Mass. Estimated cost, $2,000,000. Noted Aug. 15.

MIDLAND.—The city will install a water testing station and plans to install a filter plant. S. A. Greeley, Schiller Building, Chicago, Ill., engineer.

Minnesota

FAIRMONT.—The city will build a sewage disposal plant including an Imhoff tank and sludge drying beds. E. L. Lewis, city clerk.

Missouri

AURORA.—Sharp & Co. will build a 150-ton concentration plant on Bonanza Lease, and is in the market for sludge and slime tables, crushers, air compressors, drills, belts, conveyors, concrete, lumber, and mill hardware. Estimated cost, $45,000.

AURORA.—Stanley & Co. will build a 150-ton concentration plant on Foster Lease, and is in the market for drills, hoists, sludge, tables, boilers and crushers. Estimated cost, $45,000.

DUENWEG.—The St. Louis Mining Co., 721 Main St., Joplin, will remodel its 150-ton concentration plant and is in the market for sludge and slime tables, small motors, engine, boilers, crushers, drills, conveyors, belts, mill hardware and roofing, etc. Estimated cost, $25,000. J. Blair, superintendent.

JOPLIN.—The Julian Mining Co. will build a 150-ton concentration plant south of Four Corners, and is in the market for sludge and slime tables, crushers, lumber, roofing, air compressors, drills, belts, ore cans, ore cars, engine, boilers, concrete, mill hardware, conveyors, etc. Estimated cost, $45,000. Charles McDonald, superintendent.

JOPLIN.—The Kansas Line Mining Co. will remodel its 200-ton concentration plant near Kansas State Line, and is in the market for sludge and slime tables, ore cars, lumber, roofing, mill hardware, crushers, air compressors, belts, drills, conveyors, engine, boilers, etc. Estimated cost, $40,000. G. Meese, superintendent.

KANSAS CITY—The Talbot Reel & Manufacturing Co., Lydia Ave. and 13th St., has awarded the contract for the construction of two factory buildings, one 2-story, 55 x 130 ft. and one 2-story, 69 x 130 ft., for the manufacture of gunsights and binoculars, to Hoffman Bros., Ridge Building. Estimated cost, $140,000.

MANSFIELD.—The Mansfield Mining and Development Co. will build a 250-ton concentration plant, and is in the market for sludge and slime tables, ore crushers, belts, drills, ore cans, ore cars, lumber, mill hardware, conveyors and air compressors. Estimated cost, $65,000. J. R. Sardage, superintendent.

RICHMOND.—The city will build a filtration plant. J. W. Kirkpatrick, city clerk.

ST. LOUIS.—The Monsanto Chemical Co., 1800 South 2nd St., has awarded the contract for the construction of a 3-story, 90 x 110 ft. chemical factory, to Jas. H. Bright Contracting and Building Co., 706 Chestnut St. Estimated cost, $118,000.

WACO.—The Butler Bros. Mining Co. will build a 250-ton concentration plant, and is in the market for crushers, belts, engine, boilers, lumber, concrete, ore cans, ore track, ore cars, mill hardware, sludge and slime tables, air compressors, pipe and conveyors. Estimated cost, $65,000.

WACO—Frank Danciade will build a 250-ton concentration plant at his mine, and is in the market for sludge and slime tables, crushers, belts, lumber, mill hardware, concrete conveyors, air compressors, composition roofing, engine, boilers and drills. Estimated cost, $65,000.

Nebraska

LINCOLN.—The Board of Regents, c/o J. S. Dales, secretary, Station A., will build a 2-story, 48 x 90 ft., pathology and hygiene building. Estimated cost, $40,000.

New Jersey

BAYONNE.—The Taintor Manufacturing Co., 1st St. and Lexington Ave., will make improvements and build an addition to its plant for the manufacture of whiting, etc. Estimated cost, $50,000.

HARRISON.—The Crucible Steel Co., Harrison, has awarded the contract for the construction of a 1-story, 88 x 120 ft., open hearth building, 1-story, 26 x 300 ft., shipping building, 1-story, 28 x 300 ft., ordnance building, 1-story, 10 x 18 ft., pump house and a 1-story, 10 x 40 ft., oil storage building, on South 4th St. and Penn. Railroad, to W. H. and F. W. Crane, Woolworth Building, New York City. Estimated cost, $125,000, plus percentage.

JERSEY CITY.—The Interstate Chemical Co., 12 Bayview Ave., has awarded the contract for the erection of a 4-story, brick

factory and storage building on Garfield Ave., to Wm. R. Whyte, 36 Oakland Ave. Estimated cost, $15,000.

NEWARK.—The Board of Education, City Hall, will build a 3- and 4-story, 250 x 250 ft., reinforced concrete and steel vocational school, including a chemical laboratory, on a site near Morris Canal. Estimated cost, $500,000. L. Sonntag, City Hall, architect.

NEWARK.—The Linden Tanning Co. will build a 1-story, 60 x 60 ft., brick factory on Frelinghuysen Ave. Estimated cost, $8000. W. E. Lehman, 738 Broad St., architect.

PAULSBORO.—The Fort Mifflin Shipbuilding Corporation, Widener Building, Philadelphia, Pa., will build a new shipbuilding plant to include a 1-story, 60 x 580 ft., plate shop, 1-story, 120 x 175 ft., plate shop, 1-story, 76 x 350 ft., forge shop, 1-story, 60 x 175 ft., copper shop, 2-story, 60 x 200 ft., paint works, 1-story, 100 x 530 ft., erecting shop and a 2-story, 100 x 530 ft., joiner shop. L. A. Gilliam, general manager.

New York

KINGS PARK.—The State Hospital Commission, Capitol, Albany, has awarded the contract for the construction of extension to the sewage disposal plant at Kings Park State Hospital, to the N. Y. Sewage Disposal Co., 37 East 28th St., New York City. Estimated cost, $15,037.

LYONS FALLS.—Moyer & Pratt has awarded the contract for the construction of a 2-story, 100 x 105 ft. paper mill, to L. W. Charlebois, 841 Main St., Watertown. Estimated cost, $50,000.

SYRACUSE. — The Semet-Solvay Co., Milton Ave., has awarded the contract for the construction of a 100 x 200 ft., No. 3 Standard Building, to the Austin Co., 16112 Euclid Ave., Cleveland, O. Estimated cost, $73,900.

TOMPKINSVILLE. — The Bureau of Yards and Docks, Navy Dept., Washington, D. C., will build a laboratory and office building here. C. O. Parks, chief.

North Dakota

FARGO.—The Board of Education, E. Guthrie, clerk, has awarded the contract for the construction of a 3-story, brick and concrete high school to include laboratory, to B. J. Cheney Co., 716 South 11th St., Minneapolis, Minn. Estimated cost, $215,000.

Ohio

CANTON.—The Canton Sheet Steel Co. will build an addition to its steel mill to include machine shop, forge shop and rolling mills. Estimated cost, $750,000.

CANTON.—The Timkin Roller Bearing Co., Deuber St., will build a 1-story, 100 x 250 ft. concrete, brick and steel factory. Estimated cost, $50,000.

DELAWARE.—The K. & W. Rubber Co., c/o Ora Keichbaum, Ashland, will build a 2-story, 50 x 200 ft. brick and steel factory, for the manufacture of rubber. Estimated cost, $75,000.

CLEVELAND.—The Boro of New Brighton, New Brighton, Pa., will build a brick and reinforced concrete sewage disposal plant. Estimated cost, $60,000. R. W. Pratt, 708 Hippodrome Building, engineer.

CLEVELAND.—The Hughes-Keenan Co., 260 North Mulberry St., Mansfield, has purchased an 8-acre site and will build a plant for the fabrication of steel, here. The company recently increased its capital stock from $25,000 to $200,000.

CLEVELAND.—The Lake Erie Smelting & Refining Co., 7900 Bessemer Building, has awarded the contract for the construction of a 2-story, 40 x 54 ft., reinforced concrete, brick and steel factory at 7800 Bessemer St., to Riley Construction Co., 806 Leader-News Bldg. Estimated cost, $15,000.

LORAIN.—The Cleveland Macadam Co., 1040 Leader-News Bldg., will build a steel and brick plant and shipyard. Estimated cost, $500,000.

SANDUSKY.—The Ohio Tread & Tire Co. has awarded the contract for the construction of a 2-story, 60 x 80 ft., reinforced concrete and brick factory, to Wm. Dortzbach & Bros., Sandusky. Estimated cost, $20,000.

Oklahoma

GARDIN — The Amy T. Mining Co., Miami, will build a 300-ton concentration plant, and is in the market for sludge and slime tables, ore cars, crushers, belts, lumber, concrete, mill hardware, air compressors, track, gas engine, boilers, steam engine, wire and cables. Estimated cost, $65,000. J. Buckey, superintendent.

GARDEN.—The Shelton Mining Co. will build a 250-ton concentration plant, and is in the market for boilers, drills, sludge and mining machinery, mill hardware, crushers, belts, etc. Estimated cost, $65,000. F. Childers, superintendent.

HOCKERVILLE.—The Lucky Jennie Mining Co., Miami, Okla., will build a 300-ton concentration plant, and is in the market for electric motors, boilers, engine, belts, slime tables, crushers, air compressors, drills, mill hardware, roofing, conveyors, etc. Estimated cost, $65,000. G. Sullivan, superintendent.

HOCKERVILLE.—The St. Louis Smelting and Refining Co., Baxter Springs, Kan., will build a 250-ton concentration plant, and is in the market for sludge and slime tables, drills, belts, crushers, air compressors, conveyors, etc. Estimated cost, $63,000. R. B. Kropp, superintendent.

HOCKERVILLE.—The Union Mining Co. will remove and remodel its 200-ton concentration plant, and is in the market for two electric motors, sludge and slime tables, mill hardware, concrete, roofing, air compressors, drills, pipe and crushers. Estimated cost, $25,000. Robert Qualls, superintendent.

MIAMI.—The Amalgamated Co. will build a 250-ton concentration plant, and is in the market for sludge and slime tables, motors, engine, boilers, crushers, lumber, mill hardware, concrete, roofing, conveyors, drills, wire cables, ore cans and cars. Estimated cost, $65,000. H. L. Huddeston, Webb City, Mo., superintendent.

MIAMI.—The Atoka Mining Co. will build a 300-ton concentration plant near Bob White lease, and is in the market for sludge tables, gas engines, crushers, compressors, drills, belts, conveyors, etc. Estimated cost, $65,000. E. M. Applegate, superintendent.

MIAMI.—The Miami Metal Co. will build a 300-ton concentration plant near Picher, and is in the market for electric motor, gas engine, air compressors, belts, mill hardware, mill lumber, crushers, sludge and slime tables, etc. Estimated cost, $65,000. J. R. Sadler, superintendent.

MONARCH.—The Vanwiser and Warren Co. will build a 250-ton concentration plant, and is in the market for mill hardware, engine, boilers, sludge and slime tables, belts, crushers, conveyors, etc. Estimated cost, $65,000. J. Warren, superintendent.

MUSKOGEE. — The Gasomne Co. will build a gasoline refinery. J. T. May, president.

PICHER.—The Golden Rod Mining Co. will build two 250-ton concentration plants, and is in the market for motors, engine, boilers, crushers, sludge tables, air compressors, drills, mill hardware, mill lumber, pipe, roofing. Estimated cost, $65,000. G. Smoyer, superintendent.

PICHER.—The LaSalle Mining Co., Joplin, Mo., will remodel its 250-ton concentration plant, and is in the market for pumps, piping, belts, roofing, sludge tables, cement, lumber, drills, conveyors, crushers, air compressors, etc. Estimated cost, $20,000. A. E. Badelari, superintendent.

PICHER. — The Mogul Mining Co., Miami, will build a 250-ton concentration plant, and is in the market for sludge and slime tables, jigs, belts, engine, boilers, roofing, lumber, concrete, crushers, air compressors, drills, wire cables, conveyors, ore cans, ore bins, ore cars and track. Estimated cost, $65,000. A. E. Dunlap, superintendent.

POTEAU.—The city will build a filtration plant. C. M. Bagwell, mayor.

TATUMS.—The Ardmore Lubricating Oil Co. will build a refinery here and sink test well for oil.

WALTERS.—The Blue Ribbon Oil & Refining Co. will build a refinery; capacity, 1000 barrels.

Pennsylvania

CHESTER.—The American Steel Foundries, 30 Church St., New York City, has awarded the contract for the construction of a 1-story, 25 x 60 ft., addition to its foundry at Thurlow Station, near Chester, to R. H. Scroggins & Son., Crozer Bldg.

GLENSHAW.—The Pittsburgh Mining Machinery Co., 1st National Bank Building, Pittsburgh, will build a 1-story, 65 x 80 ft., addition to its plant. Estimated cost, $15,000.

MARCUS HOOK.—The National Aniline & Chemical Co. has awarded the contract for the construction of a 2-story, 106 x 196 ft., No. 9 type, modified building, to the Austin Co., 16112 Euclid Ave., Cleveland, O. Estimated cost, $140,000.

PHILADELPHIA.—Baugh & Sons Co., 20 South Delaware St., will build a 1-story, 100 x 300 ft. addition to its plant on Morris St., for the manufacture of chemicals.

PHILADELPHIA.—The Fibre-Graphite Manufacturing Co., 34 South 17th St., will make alterations and improvements in its plant on Wakefield St. Estimated cost, $5000.

Rhode Island

WOONSOCKET.—The Star Carbonizing Co. will build a 2-story, 52 x 178 ft. brick factory on Diamond Hill road. Estimated cost, $45,000. W. F. Fontain, North Main St., engineer.

Texas

CARLSBAD.—The Board of Directors, State Tuberculosis Sanatorium, has awarded the contract for the construction of a sewage disposal plant and sewer extensions, to Dalton & Campbell, Dallas. Estimated cost, $23,000.

TEMPLE.—The city will build an additional unit at sewage disposal plant. Estimated cost, $7500. Address The Mayor.

WACO.—The city will install a settling basin at filtration plant. Estimated cost, $26,811. E. L. Fulkerson, manager of city water works.

WICHITA FALLS.—J. A. Fisher and others will build an oil refinery, daily capacity 1000 barrels.

Washington

SEATTLE.—C. L. Glasgow, New York City, has awarded the contract for the construction of a 1-story, 41 x 175 ft., mill construction plant for the manufacture of oxygen gas and welding appliances, on East Marginal Way and Spokane St., to James Black Masonry & Contracting Co., Alaska Building. Estimated cost, $30,000.

Wisconsin

CABLE.—The Sunbeam Chemical Co., 1742 Ogden Ave., Chicago, Ill., is building a 75 x 300 ft., factory here, and will add other units later.

CARROLLVILLE.—The American Tar Products Co. has awarded the contract for the construction of a 1-story, 60 x 90 ft., factory, to Meredith Bros., 1043 Kinnickinnic Ave., Milwaukee. Estimated cost, $20,000.

GREEN BAY.—The Northwestern Engineering Co., Inc., has awarded the contract for the construction of a 30 x 32 x 160 ft. addition to its fabricating plant, to L. Hanson. Estimated cost, $30,000.

MILWAUKEE.—Eckert Bros., 1118 26th St., has awarded the contract for the construction of a 3-story, 64 x 147 ft., brick and mill construction tannery, to Riesen Bros., 1st National Bank Building.

MILWAUKEE.—J. Schlitz Brewing Co., 3rd and Galena Sts., has awarded the contract for the remodeling of its carbonic gas plant, to W. Woeflein, 86 Michigan St.

Canada

Ontario

ELMIRA.—The Elmira Rubber Co. will build an addition to its plant. Estimated cost, $30,000.

WALKERVILLE.—The Walkerville Water Co., Sandurch St., will install a 7,000,000 gal. filter. Estimated cost, $250,000. C. D. Brown, 86 Lincoln Road, secretary.

WELLAND.—The Dillon Alloys Co., Ltd., 122 Hellens Ave., has awarded the contract for the construction of a 1-story, melting building, forge shop, boiler house, producer house, etc., to the Standard Steel Construction Co., Port Robinson. Estimated cost, $150,000.

Industrial Notes

THE HALCOMB STEEL Co. has opened an office in Room 702, Connecticut Mutual Life Insurance Bldg., 36 Pearl Street, Hartford, Conn. Mr. E. L. Reed will be in charge.

THE QUIGLEY FURNACE SPECIALTIES Co., New York, has secured contract for a powdered coal plant from the Whitaker Glessner Company, Beach Bottom Works, West Virginia to furnish 4 tons of powdered coal fuel per hour to supply 20 furnaces for heating 6-in. shell forgings. This equipment is arranged for large extensions for future applications in other departments in the mills including boilers.

THE ELECTRIC FURNACE Co., Alliance, Ohio, has opened a New York office at 15 Park Row. Mr. D. D. Miller is in charge.

The Board of Directors of the MARDEN, ORTH & HASTINGS CORP. held a meeting on Aug. 28 at which Mr. Arthur C. Trask was

elected vice-president of the Corporation with headquarters in Chicago. Mr. Trask's resignation as secretary of the Corporation was accepted, and Mr. Walter O. Hastings was elected to this office. Mr. Trask has been seventeen years with the concern, while Mr. Hastings is one of the three members of the partnership which, in 1906, took over the business founded by James A. Murdock in 1837. Mr. M. S. Orth, President of the Corporation, is a direct descendant of Mr. Murdock. Within the last few weeks Marden, Orth & Hastings have opened new branches at 1303 Shelby Street, Louisville, Ky., and Union Trust Building, Cincinnati, Ohio.

THE CUTLER-HAMMER MFG. CO., Milwaukee, Wis., announce the opening on Sept. 3 of a branch office in the Union Trust Building, 15 & H Streets, N. W., Washington, D. C. Messrs. H. W. Knowles and C. W. Yerger will be located at the new office.

New Publications

THE MACHINERY UTILITIES CO., INC., 501 Fifth Ave., New York City: A bulletin, which is only for general industrial equipment, entitled "The Thrift Book," devoted to the utilization of idle machinery in active industries.

THE DOW CHEMICAL COMPANY, Midland, Mich.: A booklet entitled "Dow Chemicals."

CONCRETE IN ARCHITECTURE AND ENGINEERING, Vol. I, No. 1, dated June, 1918, published bi-monthly by the Portland Cement Association, 111 West Washington St., Chicago, Ill. This Association has also published a booklet on "Concrete Tanks for Oil Conservation."

THE UNCOLORED STORY OF AMERICAN DYES. By John Walker Harrington. This appeared in the Evening Post Magazine, May 11, 1918, and has been reprinted in booklet form by the National Aniline & Chemical Company, Inc., 21 Burling Slip, New York City.

BUILDING CONSTRUCTION. By R. I. Webber. Bulletin No. 25, Vol. XIII, No. 1, dated January, 1918, issued by The Pennsylvania State College's Engineering Experiment Station, reprinted from the Annual Report for 1916-1917.

SCHOOL OF MINES AND METALLURGY, Univ. of Missouri, Rolla, Mo. Bulletin, March, 1918, Vol. 10, No. 2, which is the 1917-1918 catalog.

THE EVOLUTION OF NATIONAL SYSTEMS OF VOCATIONAL REEDUCATION FOR DISABLED SOLDIERS AND SAILORS. Bulletin No. 15, (Reeducation Series No. 3). By Douglas C. McMurtrie, issued by the Federal Board of Vocational Education, May, 1918.

REFERENCE MATERIAL FOR VOCATIONAL AGRICULTURAL INSTRUCTION. Bulletin No. 14, Agricultural Series No. 2, issued for the Federal Board of Vocational Education, Washington, D. C.

CASE-HARDENING, issued from the Carnegie Library of Pittsburgh, reprinted from the monthly bulletin, March, 1918.

STANDARD LABORATORY TESTS OF COAL-COKE BYPRODUCTS, issued by the Scientific Materials Company, Pittsburgh, Pa., dealing with acid-wash tests for benzol, boiling-point determinations, coal and coke examinations, apparatus for gas examination, specific gravity apparatus, stills and fractionating apparatus for light-oil, wash-oil and tar testing and tar—special apparatus for tar testing. This booklet contains 32 pages and is well illustrated.

MONTHLY REVIEW OF THE U. S. BUREAU OF LABOR STATISTICS. Vol. VI, June, 1918, No. 6. Issued by the U. S. Department of Labor, Bureau of Labor Statistics, Washington, D. C.

THE BULLETIN, Vol. V, No. 11, Series of 1918, published by the Pennsylvania Department of Labor and Industry, Harrisburg, Pa.

NEW U. S. GEOLOGICAL SURVEY PUBLICATIONS: Platinum and Allied Metals in 1917. By James M. Hill. (Pages 11-21, Mineral Resources, 1917, Part I), published June 21, 1918. Gems and Precious Stones in 1916. By Waldemar T. Schaller. (Pages 887-899, Mineral Resources, 1916, Part II), published June 27, 1918. Bauxite and Aluminum in 1917. By James M. Hill. (Pages 1-9, Mineral Resources, 1917, Part I), published June 21, 1918. Arsenic, Bismuth, Selenium, and Tellurium in 1917. By Joseph B. Umpleby. (Pages 23-35, Mineral Resources, 1917, Part I), published June 19, 1918. Strontium in 1917. By James M. Hill. (Pages 5-6, Mineral Resources, Part II), published June 19, 1918. Gold and Silver in 1916 (General Report). By H. D. McCaskey and J. P. Dunlop. Pages 679-721, (Mineral Resources, 1916, Part I), published May 7, 1918. Fuel Briquetting in 1917. By C. E. Lesher. (Pages 1-3, Mineral Resources, 1917, Part II), published May 6, 1918. Cadmium in 1917. By C. E. Siebenthal. (Pages 49-53, Mineral Resources, 1917, Part I), published July 12, 1918. Sulphur, Pyrites, and Sulphuric Acid in 1917. By Philip S. Smith. (Pages 19-62, Mineral Resources, 1917, Part II), published July 10, 1918.

NEW BUREAU OF STANDARD PUBLICATIONS: Bulletin, Vol. 14, No. 1, being a collection of scientific papers on determination of degrees of uniformity of bars for magnetic standards; thermoelcetric measurement of critical ranges of pure iron; study of electromagnet moving coil galvanometers for use in alternating current measurements; standard substances for calibration of viscometers; an "average eye" for heterochromatic photometry, and comparison of flicker and equality-of-brightness photometer; emissivity of straight and helical filaments of tungsten; aneroid calorimeter for specific and latent heats; and wave lengths of stronger lines in helium spectrum. Scientific Paper 318, "Application of Dicyanin to Photography of Stellar Spectra." By Paul W. Merrill. Technologic paper No. 93, "Glasses for Protecting the Eyes from Injurious Radiations." By W. W. Coblentz and W. B. Emerson. Technologic paper No. 107, "Comparative Test of Chemical Glassware." By P. H. Walker and F. W. Smither. Circular No. 13, "Standard Specifications for Incandescent Electric Lamps." Technologic Paper No. 101, Tests of Large Bridge Columns. By J. H. Griffith and J. G. Bragg, issued June 27, 1918. Price, $0.30. Technologic Paper No. 113, Determination of Permeability of Balloon Fabrics. By Junius David Edwards, issued July 2, 1918. Price, $0.10. Scientific Paper No. 323. Some Characteristics of the Marvin Pyrheliometer. By Paul D. Foote, issued June 28, 1918. Price, $0.10. No. 73, entitled "Copper" issued June 25, 1918. Price, 20 cents, sold through the Superintendent of Documents, Government Printing Office, Washington, D. C.

NEW BUREAU OF MINES PUBLICATIONS: Bulletin 164, Law Serial 14, Abstracts of Current Decisions on Mines and Mining. Reported from September to December, 1917. By J. W. Thompson. Technical Paper 184, Weights of Various Coals. By S. B. Flagg. Technical Paper 189, Temperature-Viscosity Relations in the Ternary System CaO-Al_2O_3-SiO_2. By Alexander L. Feild and P. H. Royster. Technical Paper 144. The Quick Detemination of Incombustible Matter in Coal and Rock-Dust Mixtures in Mines. By A. C. Fieldner, W. A. Selvig and F. D. Osgood. Bulletin 103, Mining and concentration of carnotite ores. By K. L. Kithil and J. A. Davis. Bulletin 140. Occupational hazards at blast-furnace plants and accident prevention, based on records of accidents at blast furnaces in Pennsylvania in 1915. By F. H. Willcox. Bulletin 155. Oil-storage tanks and reservoirs, with a brief discussion of losses of oil in storage and methods of prevention. By C. P. Bowie. Technical Paper 170. The diffusion of oxygen through stored coal. By S. H. Katz. Technical Paper 172. Effects of moisture on the spontaneous heating of stored coal. By S. H. Katz and H. C. Porter. Technical Paper 194. Report of the Committee on the Sandardization of Mining Statistics. Compiled by Albert H. Fay.

THE JONATHAN BARTLEY CRUCIBLE CO., Trenton, N. J., issue a well illustrated and instructive booklet on Graphite Crucibles for Foundry Practice.

MICHIGAN COLLEGE OF MINES, Houghton, Mich.: Year Book, 1917-1918. Announcement of courses for 1918-1919.

SOTH DAKOTA STATE SCHOOL OF MINES, Rapid City, South Dakota, April, 1918: Annual catalog 1917-1918, with announcements for 1918-1919.

NEW U. S. DEPARTMENT OF THE INTERIOR BULLETIN: Mineral Resources of the United States, 1917. Part I: 5, "Cadmium in 1917," by C. E. Siebenthal; 6, "Gold, Silver, Copper, Lead and Zinc in the Eastern States in 1917," by James M. Hill. Part II: 4, "Sulphur, Pyrites, and Sulphuric Acid in 1917," by Philip S. Smith; 5, "Magnesite in 1917," by Charles G. Gale and Ralph W. Stone; 6, "Talc and Soapstone in 1917," by J. S. Diller; 7, "Gypsum in 1917," by Ralph W. Stone; 8, "Graphite in 1917," by Henry G. Ferguson; 12, "Mica in 1917," by Waldemar T. Schaller.

THE HOUGHTON INDUSTRIAL DIGEST is the new publication of E. F. Houghton and Co., Philadelphia, Pa., dated August, 1918. This publication will be issued every month. one issue will deal with "textiles" and the next issue with "metal working," etc.

THE EFFECT OF ADDITION AGENTS IN FLOTATION. A bulletin dated Nov., 1917, from the School of Mines and Metallurgy, Rolla, Mo. Most of the material in this bulletin appeared in METALLURGICAL AND CHEMICAL ENGINEERING, in the Dec. 15, 1917, Jan. 15, 1918, and Mar. 1, 1918, issues.

"FUEL FACTS" is the name of a new publication published by the United States Fuel Administration, Washington, D. C. This is dated Aug. 1, 1918.

"TUNGSTEN" is the title of an attractive illustrated booklet issued by the TUNGSTEN PRODUCTS MINING CO., Boulder, Colo.

"THE GLASS INDUSTRY AS AFFECTED BY THE WAR" is the Tariff Information Series —No. 5, issued by the United States Tariff Commission, Washington, D. C., and deals with new branches of the industry, changes in manufacture and trade due to war conditions, holding export and domestic trade after the war, the glass trade of European countries, and testimony of leading American manufacturers.

ANALYSIS OF CANADIAN FUELS. Compiled by Edgar Stansfield and J. H. H. Nicolls. Bulletin No. 23 issued by the Canadian Department of Mines, Ottawa, Canada.

NEW BUREAU OF MINES PUBLICATIONS. Bulletin 145. Measuring the temperature of gases in boiler settings. By Henry Kreisinger and J. F. Barkley. Technical Paper 187. Sing viscosity tables for blast-furnace work. By A. L. Feild and P. H. Royster. Bulletin 123. Analyses of mine and car samples of coal collected in the fiscal years 1913 to 1916. By Arno C. Fieldner, Howard I. Smith, J. W. Paul and Samuel Sanford. Technical Paper 91. A convenient multiple-unit calorimeter installation. By J. D. Davis and E. L. Wallace. Monthly statement of coal-mine fatalities in the United States May 1918. Compiled by Albert H. Fay. This booklet gives a list of permissible explosives, lamps, and motors tested prior to June 30, 1918. Price, $0.05.

Manufacturers' Catalogs

THE CHICAGO BELTING CO., Chicago, Ill., has issued an attractive catalog entitled "To Users of Belting" which contains 80 pages, giving views of its plant and a brief description of the various processes used in making belting.

UNITED IRON WORKS CO., Kansas City, Mo.: Bulletin No. 318 describing and illustrating Pomona duplex plunger power pumps.

THE GILBERT & BARKER MFG. CO., Springfield, Mass.: Catalog B illustrating and describing its different types of gas furnaces. This company also calls attention to a booklet on its process for burning fuel oil under low pressure.

THE TORSION BALANCE CO., New York City: Catalog No. 34 on "Torsion Balance," illustrating the many different balances.

THE HYDRAULIC PRESS MFG. CO., Mount Gilead, Ohio: Catalog No. 43 which describes and illustrates H-P-M hydraulic valves and fittings, hydraulic presses, pumps, accumulators and intensifiers for every high-pressure purpose.

THE DUST RECOVERING & CONVEYOR CO., Cleveland, Ohio, calls attention to Bulletin No. 5, August 1, 1918, on pneuamtic conveying.

T. SHRIVER & CO., Harrison, N. J., has issued an attractive catalog on filter presses for all purposes. The catalog contains 44 pages and is well illustrated.

LEEDS & NORTHRUP CO., 4901 Stenton Ave., Philadelphia, Pa. Catalog 87, entitled "The Potentiometer System of Pyrometry and Temperature Control" which contains 60 pages and is illustrated with half-tones and charts. This catalog deals with potentiometer indicators, curve drawing recorders, multiple point recorders, temperature control apparatus, transformation point apparatus, precision potentiometers, thermocouples and optical pyrometers.

THE PYROLECTRIC INSTRUMENT COMPANY, 636 East State Street, Trenton, N. J., calls attention to Circular No. 11 on the Northrup-Ajax High Frequency Induction Furnace which is available in small units for laboratory and scientific investigations.

THE BASTIAN-BLESSING COMPANY, W. Austin Ave. at La Salle St., Chicago, Ill., has issued a catalog on Rego welding and cutting apparatus, which gives prices of apparatus.